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TECHNICAL REPORT GL-81-6

STRUCTURAL ANALYSIS COMPUTER PROGRAMS FOR RIGID MULTICOMPONENT PAVEMENT STRUCTURES WITH DISCONTINUITIES--WESLIQID AND WESLAYER

Report 3

MANUAL FOR THE WESLAYER FINITE ELEMENT PROGRAM

by

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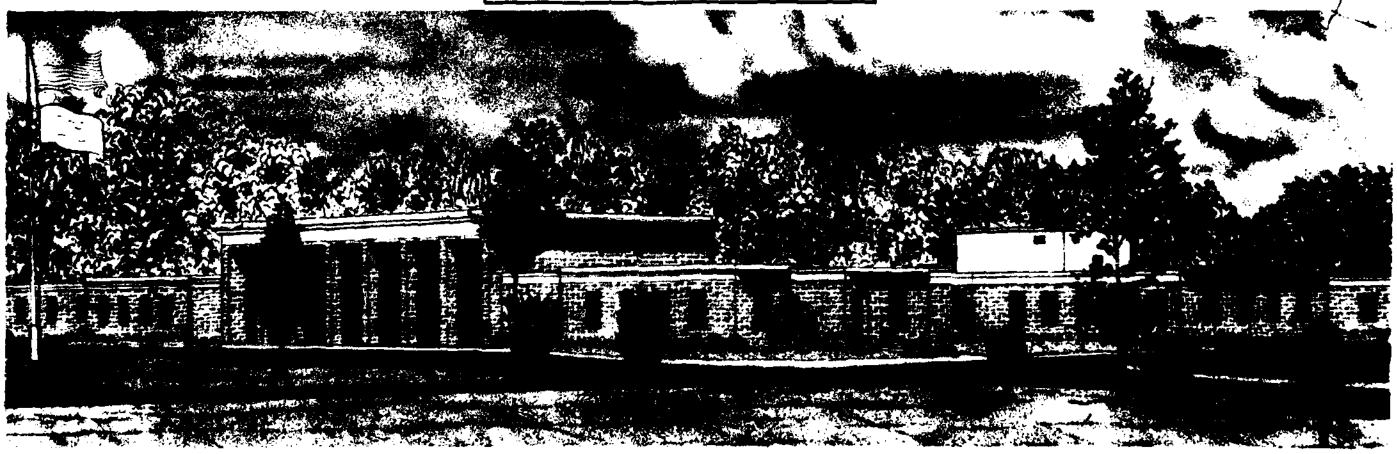
May 1981

Report 3 of a Series

Approved For Public Release; Distribution Unlimited



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This study was conducted to develop finite element computer programs to calculate stresses and deflections in rigid multicomponent pavements with cracks and joints, as well as in the supporting subgrade soil, subjected to loads and temperature warping. This report is presented as a user's manual for the WESLAYER program, which deals with pavements on layered elastic solids. The pavement can have full or partial loss of subgrade support over designated

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20. ABSTRACT (Continued).

regions of the pavements. Multiple-wheel loads can be used in the computation and the number of wheels is not limited. Because of large storage space needed and long computer time required to obtain solutions, the program is limited to only a two-slab system.

The nature of the computer program and its program logic are first delineated, followed by a general discussion on the efficient and correct use of the program. An input guide to the computer program is presented with a detailed explanation for each input variable. Example problems with input data and output printouts are presented.

PREFACE

The study described herein was sponsored by the Office, Chief of Engineers, U. S. Army (OCE), as a part of the Mobility and Weapons Effects Technology RDT&E Project No. 4A762719AT40, Work Unit 001, "Airfield Pavement Design and Parametric Sensitivity Analysis," and Work Unit 003, "Rigid Airfield Pavement Load-Deformation Response Analysis."

This report is Report 3 of a three-report series concerning the computer programs WESLIQID and WESLAYER, which provide for analysis of rigid multicomponent pavements with discontinuities on liquid foundations (WESLIQID) and on linear layered elastic solids (WESLAYER). This report is a user's manual for WESLAYER. Report 1 presented the theoretical background of the programs and numerical results and discussed the capability and logic of the two programs. Report 2 was a user's manual for the WESLIQID program.

The study was conducted by the U. S. Army Engineer Waterways Experiment Station (WES), Geotechnical Laboratory (GL), under the general supervision of Dr. Don C. Banks, Acting Chief, GL; Dr. Paul F. Hadala, Assistant Chief, GL; and Mr. Alfred H. Joseph, Chief, Pavement Systems Division (PSD), GL. Dr. Yu T. Chou, PSD, was in charge of the study and is the author of the report. Professor Y. H. Huang of the University of Kentucky, who originally developed the computer programs, assisted in the study.

COL John L. Cannon, CE, and COL Nelson P. Conover, CE, were Commanders and Directors of the WES during this study and the preparation of this report. Mr. Fred R. Brown was Technical Director.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
Fahrenheit degrees	0.555	Celsius degrees or Kelvins*
feet	0.3048	metres
inches	2.54	centimetres
pounds (force)	4.448222	newtons
pounds (force) per cubic inch	0.2714	megapascals per metre
pounds (force) per inch	175.1268	newtons per metre
pounds (force) per square inch	6.894757	kilopascals

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = 0.555 (F - 32). To obtain Kelvin (K) readings, use: K = 0.555 (F - 32) + 273.15.

STRUCTURAL ANALYSIS COMPUTER PROGRAMS FOR RIGID MULTICOMPONENT PAVEMENT STRUCTURES WITH DISCONTINUITIES--WESLIQID AND WESLAYER

MANUAL FOR THE WESLAYER FINITE ELEMENT PROGRAM

PART I: INTRODUCTION

Background

1. The U. S. Army Corps of Engineers (CE) has realized for many years that much of the maintenance of rigid pavements is associated with cracks and joints. Current CE rigid pavement design procedures have certain limitations that were imposed by the state of the art at the particular stage of development. During the development of the procedure, it was necessary to make simplifying assumptions and, in many instances, to ignore the effects of cracks and joints. Since the advent of high-speed computers and the development of the finite element method, a more comprehensive investigation of the state of stress at pavement joints, cracks, and other locations in multicomponent pavement structures than previously possible can now be achieved. Consequently, a better and more reasonable design procedure may be developed for rigid pavements.

Purpose

2. The development of the finite element programs and the analysis of computed results are presented in Report 1 of this series. This report presents a user's manual for a computer program named WESLAYER. The program computes the state of stress in a rigid pavement supported on a layered elastic foundation, as well as in the supporting subgrade soils.

Scope

3. The computer program is described in this report to give users a concise picture of the program without reference to Report 1. The logic of the programming is explained with the illustration of a flowchart. An input guide to the computer program is given, and four example problems are presented to illustrate input procedures for use of the computer program. The outputs of the example problems are explained.

PART II: PROGRAM DESCRIPTION

4. This report describes a finite element computer program named WESLAYER programmed for the analysis of concrete pavements subjected to multiple-wheel loads. The program is developed for a subgrade soil represented as a linear layered elastic solid. Any number of layers can be accommodated. Because of the assumption of an elastic soil, vertical force at one nodal point in the subgrade causes vertical movements at all other nodes and vice versa. This behavior is different from that of a liquid foundation (WESLIQID). In the liquid foundation, the vertical force or deflection at one nodal point in the subgrade is not affected by those at other nodes.

5. The program determines stresses and displacements in the pavement and in the supporting subgrade soil due to loads and temperature warping. Part of the pavement can be out of contact with the supporting subgrade before applying the load and the temperature gradient, and the program determines the condition of contact at each nodal point after the application of loads and a temperature gradient. Input data of the programs include (a) the property and geometry of the pavement and subgrade soil, (b) the magnitude and distribution of the loads, (c) the temperature gradient, (d) gaps under the pavement at certain nodal points, if any, and (e) joint and crack conditions.

6. Multiple-wheel loads can be input and the number of wheels is not limited. Because of the large computer storage space required, the program can handle only two slabs, except for the special option where a four-slab pavement system is loaded symmetrically at the pavement's center. At the joint, the program considers only the shear transfer and assumes the moment transfer to be zero.

PART III: PROGRAM APPROACH

7. The storage space required for the program depends on the total number of elements used in the problem. An iteration scheme is used in the program so that the computation is made only for one slab at each time. This scheme results in a great reduction in computer time because the number of equations to be solved each time is reduced to only one slab. Two series of iterations are involved in the program: one is with respect to subgrade contact and the other is with respect to load transfer across the joint.

8. In the iteration with respect to subgrade contact, the contact condition at each node, i.e., whether the slab and subgrade are in contact or not, is first assumed, and the iteration with respect to load transfer proceeds until either the convergence criteria (DEL in Item 11 of the input guide, Table 1*) are satisfied or the maximum allowable number of iterations (ICL in Item 10 of Table 1) is reached. At this stage, the resulting contact condition is determined. If some nodes originally assumed in contact are found out of contact or some nodes assumed out of contact are found in contact, the newly found contact condition is assumed, and the process is repeated until the same contact condition is obtained. This can usually be achieved within only a few iterations. The only control by the user is to specify the maximum number of iteration cycles, NCYCLE . If NCYCLE = 1 , the contact condition between the slab and subgrade is known a priori, and no iterations are needed.

9. In the iteration with respect to load transfer across the joint, the computation is made successively between the left and right slabs. The vertical deflections are used for checking convergence.

10. The program carries out the computations (shown in the flowchart, Figure 1) in the following sequence:

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* The input guide (Table 1) appears in Part IV, where it is discussed in detail.

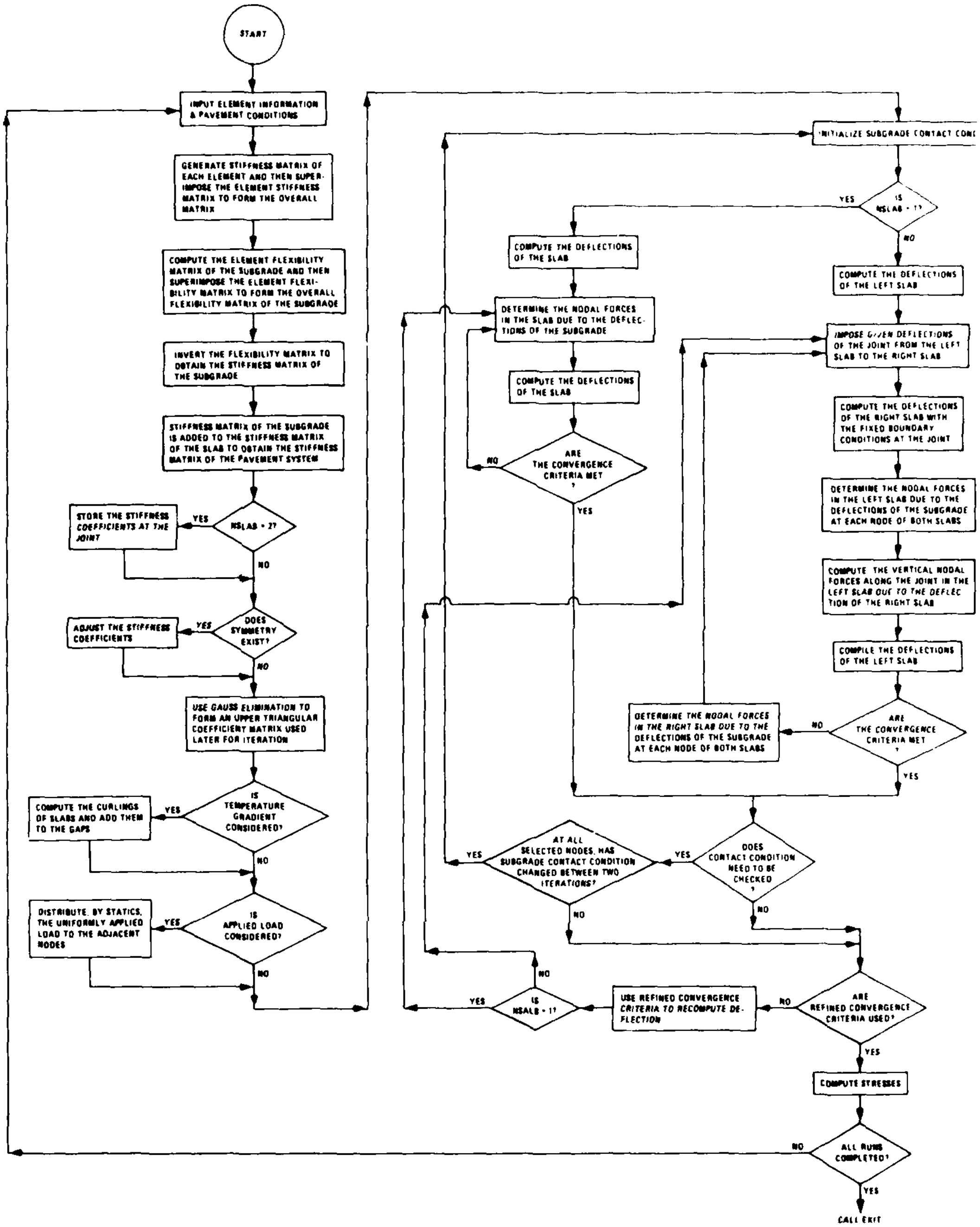

Figure 1. Flowchart for WESLAYER program

a. Generate stiffness matrix for each element (of the slabs) and then superimpose them to form an overall stiffness matrix.

b. Compute the element flexibility matrix of the subgrade and then superimpose them to the matrix of the slab to form the overall flexibility matrix.

c. Invert the flexibility matrix, using the inversion subroutine SMIN , to obtain the stiffness matrix of the subgrade.

d. The stiffness matrix of the subgrade is added to the stiffness matrix of the slab to cover the stiffness matrix of the pavement system.

e. Store the stiffness matrix adjacent to joints for later use.

f. If it is known that gaps exist under certain nodes in the subgrade soil, the gaps are read into the program to combine them with the computed curls of the slabs due to temperature warping to form the initial subgrade contact condition.

g. Determine the nodal reactive condition based on the subgrade contact condition.

h. If externally applied loads are considered, the uniformly applied loads are distributed to the adjacent nodes using statics.

i. Compute the displacements of the left slab, assuming that there is no shear and moment transfer along the joints, i.e., that slab 1 has four free edges.

j. Impose deflections along the joint from the left slab to the right slab and compute the displacements of the right slab. This is done with a fixed boundary condition at the joint.

k. Determine the nodal forces in the left slab due to the deflections of the subgrade at each node in the two slabs. (Note that this process is not needed in the WESLIQID program in that the reactive force at a certain node depends only on the deflection at that node but not elsewhere.)

l. Compute the vertical nodal forces along the joint in the left slab due to the deflection of the right slab.

m. Compute the deflections of the left slab again. The values are compared with those computed in the previous iterative cycle. If the convergence criteria are not met, the nodal forces in the right slab due to the deflections of the subgrade at each node of both slabs are

computed and the process between steps j and m are repeated until the deflections at the preselected nodes converge to a specified tolerance.

n. Once a convergent solution has been obtained or the maximum allowable number of iterative cycles has been reached (ICL in Item 10 of Table 1), the signs of the deflections at each node are compared with those of the initial (or the previous) subgrade contact condition. A change of sign at any node indicates that the contact condition at these nodes has changed. Based on the renewed subgrade contact condition, the computational process from steps a to m is repeated. The iteration process stops when either the contact condition ceases to change or the maximum allowable number of iterations (NCYCLE at Item 4 of Table 1) has been reached. Note that when the subgrade contact condition is changed, the subgrade stiffness is also changed.

o. Once the subgrade contact condition is unchanged, the computational process from steps j through m is repeated once more with a refined convergence criterion. The controlling variables in the program are ICLF in Item 10 and DELF in Item 11 of Table 1.

p. The stresses at selected nodal points are computed based on the curvature of the deflected slab, i.e., the nodal displacements.

q. Compute stresses and deflections in the subgrade if so desired.

r. Note for a single slab, i.e., NSLAB = 1 , steps j to m are skipped if a full bandwidth NB is used.

11. For a single slab, steps j and l are neglected; i.e., the left slab is the only slab.

12. In computing the subgrade reactive forces at each nodal point, Boussinesq's homogeneous analysis and the layered elastic theory are used to formulate the flexibility matrix for single-layer and multilayer subgrade soil, respectively. In the multilayer case, the layered elastic theory is not used directly at every nodal point in order to save computer time; rather, the theory is used to compute the deflections at 21 different offset points, and interpolation subroutines are used to interpolate the deflections at node j due to the load at node i.

PART IV: OPERATION OF THE PROGRAM

General Discussion

13. As with other numerical procedures for solving structural problems, the accuracy of the finite element method depends greatly on the correct use of the technique. While the computational cost and storage space increase drastically with an increased number of elements, the program does require a reasonable number of elements. The element size should be smaller near the loads and joints where stresses are transferred to another slab. In some cases, the minimum number of elements for a particular problem has to be determined by a trial-and-error procedure. It was found that an insufficient number of elements can cause the solution to diverge; this is particularly true when temperature warping is considered and gaps exist under the pavement. Also, users should be aware that the aspect ratio of an element, defined as the ratio of the larger dimension to the smaller dimension of a rectangular element, should not exceed four or five to one. It is always good practice for the beginning user of this program to familiarize himself with the program by using different numbers of elements for a particular problem and then comparing the results.

14. The input guide for the program is presented later in this Part. Special features in the correct and efficient use of the program are presented and discussed in the following paragraphs.

Dimension requirements

15. The method developed in this program can be applied only to two slabs. The dimensions of C * and G vary with the number of elements and the half bandwith and can be computed as

$$\sum_{1}^{NSLAB} (\text{total nodal points}) \times 3 \times NB \qquad (1a)$$

* Symbols used in the WESLAYER program are defined in the input guide (Table 1).

or

$$\text{(total nodal points in the slabs)}^2 \qquad (1b)$$

where NB is the half bandwidth and is equal to (NY + 2) × 2 . The symbol NY represents the number of nodes in the Y-direction. When the dimensions of C and G are changed in the main program, they should also be changed in the corresponding subroutines.

16. The dimensions of many important variables in the present program are limited and should be increased if the number of elements is increased. The limited dimensions of variables are presented as follows:

- a. The maximum nodal number (N023) is 70 and the maximum number of elements is 60. To increase element size, the dimensions of the variables DF , PPF , PF, CURL , FO , AB , NCC , REA , and REACT should be increased in accordance with the total number of nodes N023 ; and the dimension of the variable DEF is to be increased as the total number of elements.
- b. The maximum numbers of NMCF and NPRINT are 35 and 30, respectively. When the value of NPRINT is changed, the dimension of the variable NP should be changed accordingly.
- c. The dimensions of H (so is A), F , and CO are determined by the formulas

  N023 × (N023 + 1)/2; 3 × N023; and 3 × NB × NY

  respectively. Variable A is in the subroutine SMIN .
- d. The maximum number of nodes that have gaps under the pavement is 30. When this is increased, the dimensions of the variables NG and GAP should also be increased.
- e. The maximum number of loads is controlled by the variable NL . When the dimension of NL is increased, the dimensions of XDA and YDA should also be increased accordingly.
- f. The maximum number of layers is 5. If more layers are desired, the dimensions of many variables in the common block RMCOY should be changed.

Element and node numbering system

17. Beginning from the left slab and ending at the right slab,

the nodes and elements are numbered consecutively from bottom to top and then from left to right.

Symmetries

18. The application of the finite element method for analyzing rigid pavements involves solving a large set of simultaneous equations. However, because of symmetry, the number of simultaneous equations could be greatly reduced by considering only one-quarter or one-half of the slab. The symmetry is with respect to the load, the pavement geometry and property, the finite element grid layout, and the load transfer device along the joint. Users are strongly urged to take advantage of the symmetry option provided by the program to arrange the loadings in such a way that the problem becomes symmetrical. Coded data input for symmetrical example problems are presented in Part V. It should be pointed out that symmetry should not be placed at a joint.

19. When the effects due to temperature and loadings are considered separately, the computed results due to temperature alone are expected to be symmetrical with respect to the pavement geometry. For instance, the stresses and deflections are the same at the four corner nodes in a square slab subjected to a temperature warping. This may not be the case, however, if the finite element grid lines are not divided symmetrically. In practical cases, smaller elements can be used around the applied loads, which may result in a nonsymmetrical finite element grid pattern. If this is the case, the computed results due to temperature alone may not be symmetrical as they should be and consequently may affect to a certain extent the final results when the temperature effect is combined with that of the load. The error in most cases is insignificant because the load effect usually outshadows the temperature effect. Nevertheless, users should be aware of this possible discrepancy.

20. In Figure 4 of Report 2 of this series, the loads are placed at the pavement's center next to the joint. Smaller elements are used around the loads and larger elements are used elsewhere. Although the finite element pattern is symmetrical in the up-and-down direction with

respect to the pavement's center line and symmetrical in the left-and-right direction of the two-slab pavement with respect to the joint, the size of each element is not identical. Consequently, if there is no moment transfer along the joint, the computed results due to the temperature effect at nodes 1 and 57 are not equal, as they theoretically should be. Consequently, the final computed results are not strictly correct. However, the error is believed to be insignificant when the effect of applied loads is combined.

Half bandwidth

21. The definition of the half bandwidth of a matrix can be found in any structures book. The size of the half bandwidth directly influences the size of the storage space. A proper nodal numbering system may reduce the size of the half bandwidth. This is illustrated in the two different numbering systems shown in Figure 6 of Report 2 of this series. Both slabs in Figures 6a and 6b have 20 nodes and 12 elements, but the half bandwidth for the arrangement shown in Figure 6a is $(4 + 2) \times 3 = 18)$ and that of Figure 6b is $(5 + 2) \times 3 = 21$. The rule of thumb is to arrange the finite element grid with the side having fewer nodes in the vertical direction.

Weight of the concrete slab

22. In the classical Westergaard solution, the weight of the slab is not considered in the computation. The consideration of the weight of the slab is an option in this computer program. When temperature and loads are not considered and the subgrade is uniform and in full contact with the slab, the weight of the slab only causes the slab to settle uniformly and induces no bending in the slab. Consequently, stresses are not induced in the slab. In some cases, the consideration of the weight of the slab is mandatory, as discussed below.

23. The major difference in procedure between full and partial contact between the slab and the subgrade is that it is not necessary to consider the weight of the slab in the case of full contact, but the weight of the slab must be considered in the case of partial contact.

24. When problems involve only temperature warping (no externally applied forces), the weight of the slab must be considered to

avoid the possible divergence of the solution. This is particularly true when gaps exist under some of the nodes. For the case of partial contact, the weight of the slab must be considered even when temperature is not considered.

Selected points of stress computations

25. While the displacements are computed automatically for every nodal point, the stresses are computed only on request. The stress matrix is used each time when the stresses at a nodal point are computed. Some computer time can be saved if the stresses at only a few selected nodes are computed.

Temperature considerations

26. When temperature is considered, the dimensions of the two slabs must be identical.

27. The computed initial curlings are independent of the arrangement of the finite element grid pattern. The amount of initial curling at each node is computed by Equation 10b in Report 1 of this series. The only variable in Equation 10b is the distance R between the center of each slab to the node where the curling is computed.

Correctness and divergence of the obtained solution

28. Users of the computer program should always be scrupulous with the results computed. The stresses and deflections could be computed and tabulated, but the values may not be meaningful. Certain features in the program deserve special attention and are explained in the following paragraphs.

29. Number of iterations. When the number of iteration IC has reached the maximum allowable number of iteration ICL and ICLF (Item 10 of Table 1), the solution has not converged. The problem should be recomputed with larger values of ICLF (and also ICL in certain cases). However, it may be wise at this stage to see whether the solution obtained is good enough for engineering purposes. In some cases, a solution may not be obtainable if the convergence criterion is too strict. The same reasoning can be used to check the number of iteration NIC for subgrade contact against the maximum allowable

number of iteration NCYCLE . The value of ICL is not as critical as the value of ICLF ; however, a large difference between the actual value of IC (printed in the output) and the specified ICL is not recommended.

30. Reduction of relaxation factor RFJ . If convergent results cannot be obtained, the program reduces the factor automatically. A value for the relaxation factor that is too small results in a shear transfer that is too small across the joint during each iteration; consequently, the computed results could be erroneous because the convergence of the solution is artificially enforced.

31. Symmetries. When symmetry in a given direction is used and the deflections and stresses across a certain joint are supposed to be equal, the efficiency of load transfer across the joint should be input only as 100 percent. Otherwise, erroneous results will be computed.

32. Computed stresses and deflections. The solutions obtained from the finite element application are by no means completely correct; they are merely close, acceptable approximations. The correctness of the computed larger values is more important. The smaller values computed at insignificant locations of the pavement, such as at placed far away from the load, are of no significance in engineering problems.

Input Guide

33. The input guide for the program is given in Table 1, with detailed explanations of each entry presented as follows:

a. Item 1: Number of Runs Card (I5).

Notes	Columns	Variables	Entry
(1)	1-5	NRUN	Number of runs to be computed

NOTES:

(1) The number of runs is first specified at the onset of computations. The nature of the problems in each individual run is generally different. However, results of one run can be used in the next run immediately followed by the input NREAD or NREAD1 . They are explained in Item 6.

Table 1. Input Guide for WESLAYER--Slabs on Layered Elastic Solids

GENERAL PURPOSE DATA FORM

PROGRAM | DATE
REQUESTED BY | PREPARED BY | CHECKED BY | PAGE OF

Item 1: Number of Run Card (I5)

NRUN	

Item 2: Identification Card (12A6)

Problem description (title) can be described in columns 1-80.

Item 3: Data Card (12I5)

NSLAB	PR	T	YM	YMS	PRS	NSYM	NOTCON	NSTORE	NPUNCH	NB	LTR

Item 4: Data Card (6I5)

NX1	NX2	NY	NCYCLE	NPRINT	NLA	NCOMP

Item 5: Stresses Print Card (16I5)

NP(1)	NP(2)	NP(3)	NP(4)	---------- NP(NPRINT)

* Continue the input until the number of NPRINT (Item 4) is satisfied.

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(Continued)

(Sheet 1 of 5)

Table 1 (Continued)

GENERAL PURPOSE DATA FORM

PROGRAM | DATE
REQUESTED BY | PREPARED BY | CHECKED BY | PAGE | OF

Item 6: Subgrade Material Properties Card (8F10.2)

E(1)	V(1)	E(2)	V(2)	E(3)	V(3)	----------
----------	----------	E(NLA)	V(NLA)			

Continue the input until the number of NLA (Item 4) is satisfied. Skip to Item 8 if the number of layered elastic subgrade NLA = 1 .

Item 7: Subgrade Layer Thickness Card (18F10.2)

HI(1)	HI(2)	HI(3)	HI(4)	----------	HI(NN)	

Continue the input until the number of NN is satisfied, where NN = NLA (Item 4). Skip to Item 8 if the number of layered elastic subgrade is 1.

Item 8: Nodal Points Coordinates Cards (8F10.5)

Card 1: X-coordinates

X(1,1)	X(1,2)	X(1,3)	----------	X(2,1)	X(2,2)	X(2,3)	----------

Card 2: Y-coordinates

Y(1)	Y(2)	Y(3)	----------	Y(NY)

Item 9: Subgrade Contact Card (16I5)

NZ(1)	NZ(2)	NZ(3)	NZ(4)	----------	NZ(NOTCON)

Continue the input until the number of NOTCON (Item 3) is satisfied. Skip to the next table if NOTCON = 0 .

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(Continued)

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Table 1 (Continued)

GENERAL PURPOSE DATA FORM

PROGRAM | DATE

REQUESTED BY | PREPARED BY | CHECKED BY | PAGE OF

Item 10: Data Card (6I5)

NGAP	NTEMP	NLOAD	NMCF	ICL	ICLF	NCK	NWT	IGNOR

Item 11: Data Card (8F10.5)

TEMP	Q	DEL	DELF	RFJ	EFF

Item 12: Concentrated Forces and Moments Card [4(I5,25,F10.2)]

NF(I)	NFF(I)	FO[NF(I)-1×3 + NFF(I)]	------------ Continue it until NMCF is satisfied.

Skip to the next item if NMCF = 0 .

Item 13: Check Convergence Card (16I5)

NODCK(1)	NODCK(2)	NODCK(3)	----------------	NODCK(NCK)

Item 14: Dowel Bar Information Card (5F10.5, E10.3)

BD	BS	WJ	PRSB	YMSB	DSM

Skip to the next item if LTR = 0 .

WES 1233

(Continued)

(Sheet 3 of 5)

Table 1 (Continued)

GENERAL PURPOSE DATA FORM

PROGRAM | DATE
REQUESTED BY | PREPARED BY | CHECKED BY | PAGE | OF

Item 15: Gaps Read In Card

Card 1: Nodal Points (16I5)

| NG(1) | NG(2) | NG(3) | ---------------- | NG(NGAP) |

Card 2: Gaps (8F10.5)

| CURL(NG(1)) | CURL(NG(2)) | CURL(NG(3)) | -------------------------------- | CURL(NG(NGAP)) |

Continue the input until the number of NGAP (Item 10) is satisfied. Skip to the next item if NGAP = 0 .

Item 16: Total Uniformly Applied Load Card (F12.2)

| RLOAD |

Skip Items 16 and 17 if NLOAD = 0 .

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(Continued)

(Sheet 4 of 5)

Table 1 (Concluded)

GENERAL PURPOSE DATA FORM

PROGRAM | DATE
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Item 17: Loading Cards

Card 1: Loading Elements (16I5)

NL(1) | NL(2) | NL(3) | NL(4) | ---------------- | NL(NLOAD) |

Continue the input until the number of NLOAD (Item 10) is satisfied.

Card 2: Load Magnitude (4F10.5)

XDA(I,1) | XDA(I,2) | YDA(I,1) | YDA(I,2) |

If the number of loaded element is greater than 1 (I_{max} = NLOAD in Item 10), continue to next data card using same format. Skip Item 16 if NLOAD = 0 .

Item 18: Subgrade Stress Card

Card 1: Number of computations (2I10)

NZZ | NR |

Card 2: Depth card (8F10.5)

ZZ(1) | ZZ(2) | --------- | ZZ(NZZ)

Card 3: Offset card (8F10.5)

XR(1) | YR(1) | XR(2) | YR(2) | ---------------- | XR(NR) | YR(NR) |

Skip item 18 if NCOMP=0

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b. Item 2: Identification Card (A80).

Notes	Columns	Variables	Entry
(1)	1-80	TITLE(12A6)	Enter the heading information to be printed with the output

NOTES:

(1) Begin each new problem with a new heading card.

c. Item 3: Data Card (16I5).

Notes	Columns	Variables	Entry
(1)	1-5	NSLAB	Number of slabs in the model
	6-10	PR	Poisson's ratio of the concrete, generally use 0.15
	11-15	T	Thickness of the concrete
	16-25	YM	Young's modulus of the concrete
(2)	26-35	YMS	Young's modulus of the subgrade
(2)	36-40	PRS	Poisson's ratio of the subgrade
(3)	41-45	NSYM	Condition of symmetry
(4)	46-50	NOTCON	Total number of nodes at which reactive pressure is initially set at zero
(5)	51-55	NSTORE	Options for thermal stress and thermal deflections: EQ.0 The values determined from the previous problem are not used, or it is a new problem EQ.1 The values determined from the previous problem are used

Notes	Columns	Variables	Entry
	56-60	NPUNCH	Option for punching values of thermal stresses and deflections on cards: EQ.0 No EQ.1 Yes
(6)	61-65	NB	Half bandwidth of the matrix
	66-70	LTR	Option for computing load transfer along the joint: EQ.0 Efficiency of shear transfer is read in EQ.1 Dowel information is read in

NOTES:

(1) The maximum number of slabs is 2.

(2) When the number of NLA is 1, i.e., the subgrade is modeled as a linear elastic solid, YMS and PRS can be any number.

(3) Assign 1 when no symmetry exists, 2 when symmetric with respect to the Y-axis, 3 when symmetric with respect to the X-axis, 4 when symmetric with respect to both the X- and Y-axes, and 5 for four slabs symmatrically loaded. When subgrade stresses and deflections are computed, symmetry should be used with caution. When either NSX or NSY is not zero, the total number of nodal reactive forces is reduced to one-half, and when both NSX and NSY are not zero, the total number of nodal reactive forces is reduced to one-quarter. Users are urged to distinguish between a four-slab pavement symmetrically loaded (assign 5 for NSYM for this case) and a single slab symmetrically loaded (assign 4 for this case). In the former case, the slabs are divided by joints and the shear transfer across the joints can be assumed either as 100 percent or as by dowel bars. The assumption of shear transfer less than 100 percent is meaningless because of the symmetrical loading. The subgrade reactive force at a node along a neutral axis is only one-half of the nodal force at the node when symmetry is not used. Symmetry should not be used at nodes along a joint.

(4) If the subgrade soil at certain nodal points is known

to be not in contact with the pavement due to pumping or plastic deformation, the subgrade reactive pressure at these nodes can be initially set at 0 to obtain speeding convergence. If NCYCLE = 1 (NCYCLE is listed in Item 4), these nodes will never be in contact. If NCYCLE > 1 , these nodes may or may not be in contact, depending on calculated results.

(5) In pavement design, engineers are interested in stresses induced by the applied load and the temperature warping. In pavement research, however, engineers tend to measure only stresses due to the applied load because thermal stresses are difficult to measure. To compute stresses and deflections by the load alone, two separate but consecutive runs have to be conducted. The first run computes the thermal stresses alone. This is done by setting NSTORE = 0 , NWT = 1 , NTEMP = 1 , NGAP > 1 (if this is the case), NOTCON > 0 (if this is the case), and NLOAD = 0 in the first run. In the second run, the stresses induced by the applied load and the temperature warping are computed by setting NSTORE = 1 , NWT = 1 , NTEMP = 1 , NGAP > 1 (if this is the case), NOTCON > 0 (if this is the case), and NLOAD equal to the actual number of loads. The differences between those values computed in the first and second runs are the stresses and deflections due to the applied load along. Note that when temperature is considered, the slab and the subgrade may be in partial contact, the principle of superposition may no longer be held true (see paragraph 47, Report 1 of this series). It should also be pointed out that in the case of the first and second runs discussed above, the measured gaps that are input should not include the gaps due to the temperature warping because they are to be computed.

(6) The half bandwidth NB should be equal to or greater than (NY + 2) × 3 , where NY is the number of nodes in the Y-direction. It was found that when the number of equations is large while the half bandwidth is small, the displacements may not converge, and a larger bandwidth should be used. For NSLAB = 1 , the solution can be obtained without iteration if a full bandwidth NB is used.

d. Item 4: Data Card (6I5).

Notes	Columns	Variables	Entry
	1-5	NX1	Number of nodes along the X-axis in slab 1
(1)	6-10	NX2	Number of nodes along the X-axis in slab 2
	11-15	NY	Number of nodes along the Y-axis

Notes	Columns	Variables	Entry
	16-20	NCYCLE	Maximum number of cycles for checking subgrade contact, generally use 10 or more
(2)	21-25	NPRINT	Number of nodes at which stresses and deflections are to be printed
	26-30	NLA	Number of layers in the subgrade
	31-35	NCOMP	OPTIONS for computing stresses and deflections in the subgrade: EQ.0 No EQ.1 Yes

NOTES:

(1) NX2 = 0 if NSLAB = 1 .

(2) The deflections at each node are computed in the program but the stresses at any node are computed only on request.

e. Item 5: Stresses Print Card (16I5).[1]

Notes	Columns	Variables	Entry
(2)	1-5	NP(I)	Nodal number whose stresses are to be printed

NOTES:

(1) Deflections are printed for all nodal points.

(2) Continue the input until the number of NPRINT (Item 4) is satisfied. Continue to next data card if NPRINT is greater than 16.

f. Item 6: Subgrade Material Properties Card (8F10.2).

Note: Skip Item 6 is NLA = 1 .

Notes	Columns	Variables	Entry
	1-10	E(1)	Young's modulus in layer 1
	11-20	V(1)	Poisson's ratio in layer 1
	21-30	E(2)	Young's modulus in layer 2

Notes	Columns	Variables	Entry
	31-40	V(2)	Poisson's ratio in layer 2
	:	:	:
		E(NLA)	:
		V(NLA)	:

g. Item 7: Subgrade Layer Thickness Card (8F10.2).

Note: Skip Item 7 if NLA = 1 .

Notes	Columns	Variables	Entry
	1-10	HI(1)	Thickness of the first layer
	11-20	HI(2)	Thickness of the second layer
		:	:
		HI(NN)	Thickness of the last layer, where NN = NLA - 1

h. Item 8: Nodal Points Coordinates Cards (8F10.5).

Card 1: X-coordinates

Notes	Columns	Variables	Entry
(1)	1-10	X(1,1)	X-coordinate of the first node of slab 1
	11-20	X(1,2)	X-coordinate of the second node of slab 1
		:	:
		X(1,NX1)	X-coordinate of the NX1 node of slab 1
(2)		X(2,1)	X-coordinate of the first node of slab 2
		X(2,2)	X-coordinate of the second node of slab 2
		:	:
		X(2,NX2)	X-coordinate of the NX2 node of slab 2

Card 2: Y-coordinates

Notes	Columns	Variables	Entry
	1-10	Y(1)	Y-coordinate of the first node

Notes	Columns	Variables	Entry
	11-20	Y(2)	Y-coordinate of the second node
		:	:
		Y(NY)	Y-coordinate of the NY node

NOTES:

(1) The nodes at both sides of the joint should be identical; i.e., if the slab length is 180 in. and 12 nodes are used in the X-direction, the coordinates of X(y,12) and X(2,1) are both 180.

(2) Skip input for slab 2 if NSLAB = 1 .

When temperature is considered, the dimensions of two slabs have to be identified. Otherwise, erroneous results will be computed.

i. Item 9: Subgrade Contact Card (16I5).

Note: Skip Item 9 if NOTCON = 0 ; i.e., the slabs are initially in full contact with the subgrade.

Notes	Columns	Variables	Entry
(1)		NZ(I)	Nodal number at which reactive pressure is initially assumed zero

NOTES:

(1) Continue the input until the number of NOTCON is satisfied. Continue to next data card if NOTCON is greater than 16.

j. Item 10: Data Card (6I5).

Notes	Columns	Variables	Entry
	1-5	NGAP	Total number of nodes at which a gap exists between slab and subgrade; assign 0 if no gap exists
	6-10	NTEMP	Condition of temperature warping: EQ.0 Temperature gradient is zero EQ.1 Temperature gradient is not zero
	11-15	NLOAD	Number of elements on which load is applied; use 0 if there is no load

Notes	Columns	Variables	Entry
(1)	16-20	NMCF	Number of concentrated nodal forces and moments that are to be read in; assign 0 if no moments or forces are applied
(2)	21-25	ICL	Maximum number of iterations allowed for coarse control; generally use 49 or more
(2)	26-30	ICLF	Maximum number of iterations allowed for fine control; generally use 199 or more
(3)	31-35	NCK	Total number of nodal points for checking convergence
	36-40	NWT	Weight of slab consideration: EQ.0 Weight is not considered EQ.1 Weight is considered
(4)	41-45	IGNOR	A parameter indicating whether the reduction of relaxation factor RFJ should be ignored: EQ.0 If RFJ is reduced EQ.1 If RFJ is not reduced whenever the results diverge

NOTES:

(1) The concentrated force is considered to be positive if it is acting downward and to be negative if it is acting upward. Positive moment follows the right-hand screw system, as shown in Figure 1 of Report 1 of this series. The program is dimensioned for 50 concentrated forces and moments. If NMCF is greater than 50, dimensions of NFF , NFI , and NF must be increased.

(2) See note 1 of Item 11. Coarse and fine controls are used before and after the subgrade contact condition is determined. For a given contact condition, coarse control is used to check the deflection criterion. Once the subgrade contact condition is finally determined, fine control

is used to obtain accurate solutions. In the case where NCYCLE = 1 , coarse control is still used prior to the use of fine control. Note ICLF should always be greater than ICL .

In some problems, ICLF may be exhausted before the criterion DELF is satisfied. Before rejecting the solution, it may be wise to check to see how far the solution is from satisfying the criterion. For instance, if DELF = 0.001 and computed convergence is 0.002 or 0.0025 and the computed results seem to be reasonable, the solution may be considered acceptable. In some problems, it may be very hard to satisfy the specified convergence criterion.

(3) Two or three points should suffice. They should be selected under or near the load where stresses and deflections are the greatest. When NSLAB = 2 , the convergence points should be selected along the joint.

(4) The use of IGNOR is to increase the flexibility of the program. In some cases, it may be desirable to check the convergence condition when the relaxation factor is fixed at a certain value. It was found that in some cases the computed results are better when the problem is computed with a constant RFJ of 0.5 than when computed with either a smaller constant RFJ or a varying RFJ (reducing automatically). For instance, if the loads are symmetrically placed on the slab, the stresses should be symmetrical at corresponding points. It was found that the magnitudes of the stresses computed at the corresponding points were much closer when computed with a constant RFJ of 0.5 than when computed otherwise. It is thus recommended to use RFJ = 0.5 or 0.1 and IGNOR = 1 in the computation if the solution can be obtained. The use of an RFJ that is too small can artificially accelerate the convergence, but the results obtained may be erroneous.

k. Item 11: Data Card (8F10.5).

Notes	Columns	Variables	Entry
	1-10	TEMP	Difference in temperature, in degrees Fahrenheit,* between top and bottom of slab: EQ.positive slab curled upward EQ.negative slab curled downward

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

Notes	Columns	Variables	Entry
	11-20	Q	Uniformly applied pressure in psi
(1)	21-30	DEL	Tolerance of convergence for coarse control; usually use 0.01
(1)	31-40	DELF	Tolerance of convergence for fine control; usually use 0.001
(2)	41-50	RFJ	Initial relaxation factor at the joint; generally use 0.5 or 0.1
(3)	51-60	EFF	Efficiency of shear transfer across the joint. It ranges from 1 to 0

NOTES:

(1) DEL and DELF correspond to ICL and ICLF in Item 10, respectively.

(2) The use of RFJ is to reduce the deflections transferred from one slab to the other. The program reduces the value of RFJ automatically when the solution diverges. When dowel bars are used, it was found that the solution can be obtained only when RFJ is reduced to 0.01. When dowel bars are not used, however, an erroneous solution was obtained when RFJ was set to 0.01.

(3) The value of efficiency across the joint varies from 0 to 1. If LTR (input in Item 3) is equal to 1, EFF must be input as 1. However, it does not mean that 100 percent shear transfer is used in the program.

No minimum value of RFJ is used in the program. However, a value too small would result in a shear transfer across the joint that is too small during each iteration, and consequently the computed results could be erroneous because the convergence of the solution is "artifically" enforced.

When the pavement geometry and loading conditions in the pavement are such that the computed results at corresponding locations in two slabs are supposed to be symmetrical, joint efficiency other than 100 percent should not be used. Otherwise, erroneous results will be computed.

l. Item 12: Concentrated Forces and Moments Card [4(I5, I5, F10.2)].

Note: Skip Item 22 if NMCF = 0 .

Notes	Columns	Variables	Entry
	1-5	NF(I)	Nodal number at which concentrated forces or moments are specified
(1)	6-10	NFF(I)	Nature of specified force at node I
(2)	11-20	FO[NF(I)-1] × 3 + NFF(I)	Concentrated force or moment at node I

NOTES:

(1) NFF(I) = 1 for vertical force, 2 for moment about X-axis, and 3 for moment about Y-axis.

(2) The magnitude of concentrated force or moment at each node input in the equation number is related to nodal number I by NF(I) - 1 × 3 + NFF(I) . For instance, if a moment about Y-axis is applied at node 13, the equation number will be (13 - 1) × 3 + 3 = 39 . Note that the nodes are numbered consecutively from bottom to top and then from left to right beginning from the first slab and ending at the last slab.

m. Item 13: Check Convergence Card (16I5).

Notes	Columns	Variables	Entry
	1-5	NODCK(1)	Nodal number of the first node at which the convergence is checked
	6-10	NODCK(2)	Nodal number of the second node at which the convergence is checked
		:	
		:	
		NODC(NCK)	Nodal number of the NCK node at which the convergence is checked

n. Item 14: Dowel Bar Information Card (5F10.5, E10.3).

Note: Skip Item 14 if LTR = 0 .

Notes	Columns	Variables	Entry
	1-10	BD	Bar diameter
	11-20	BS	Bar spacing
	21-30	WJ	Joint opening
	31-40	PRSB	Poisson's ratio of the bar

Notes	Columns	Variables	Entry
	41-50	YMSB	Young's modulus of the bar
	51-60	DSM	Modulus of dowel support

o. Item 15: Gaps Read In Cards.

Note: Skip Item 15 if NGAP = 0 .

Card 1: Nodal Points (16I5)

Notes	Columns	Variables	Entry
	1-5	NG(1)	Nodal number of the first node at which a gap exists
	6-10	NG(2)	Nodal number of the second node at which a gap exists
		:	
		NG(NGAP)	Nodal number of the NGAP node at which a gap exists

Card 2: Gaps (8F10.5)

Notes	Columns	Variables	Entry
	1-10	CURL(NG(1))	Amount of gap at node NG(1)
	11-20	CURL(NG(2))	Amount of gap at node NG(2)
		:	
		CURL(NG(NGAP))	Amount of gap at node NG(NGAP)

p. Item 16: Total Uniformly Applied Load Card (F12.2).

Note: Skip Item 16 if NLOAD = 0 .

Notes	Columns	Variables	Entry
(1)	1-12	RLOAD	Total uniformly applied load on the slab

NOTES:

(1) The total load refers to the uniformly applied load only. The total load should be divided by 2 or 4 if it is symmetric with respect to one axis (X- or Y-axis) or both the X- and the Y-axis, respectively. Additional point loads applied at nodal points are excluded.

q. Item 17: Loading Cards.

Note: Skip Item 17 if NLOAD = 0 .

Card 1: Loading Elements (16I5)

Notes	Columns	Variables	Entry
(1)	1-10	NL(1)	Element number of the first element over which load is applied
(1)	11-20	NL(2)	Element number of the second element over which load is applied
		:	:
		NL(NLOAD)	Element number of the last element over which load is applied

NOTES:

(1) Beginning from the first slab and ending at the last slab, the nodes and elements are numbered consecutively from bottom to top and then from left to right.

Card 2: Load Magnitude (4F10.5)

Notes	Columns	Variables	Entry
(1)	1-10	XDA(I,1)	Lower limit of loaded area in element I in X-direction
(1)	11-20	XDA(I,2)	Upper limit of loaded area in element I in X-direction
(2)	21-30	YDA(I,1)	Lower limit of loaded area in element I in Y-direction
(2)	31-40	YDA(I,2)	Upper limit of loaded area in element I in Y-direction

NOTES:

(1) Use -1 to +1 if the load covers the whole length of the element.

(2) Use -1 to +1 if the load covers the whole width of the element.

r. Item 18: Subgrade Stresses Card.

Note: Skip Item 18 if NCONF = 0 .

Card 1: Number of Computations (2I10)

Notes	Columns	Variables	Entry
	1-10	NZZ	Number of depths to be computed
	11-20	NR	Number of offsets at each depth to be computed

Card 2: Depth Card (8F10.5)

Notes	Columns	Variables	Entry
	1-10	ZZ(1)	Depth of first computation
	11-20	ZZ(2)	Depth of second computation
	--	--	
	--	--	
		ZZ(NZ)	Depth of the last computation

Card 3: Offset Card (8F10.5)

Notes	Columns	Variables	Entry
(1)	1-10	XR(1)	X-coordinate of first computation
	11-20	YR(1)	Y-coordinate of first computation
	21-30	XR(2)	X-coordinate of second computation
	31-40	YR(2)	Y-coordinate of second computation
	--	--	
	--	--	
		XR(NR)	X-coordinate of last computation
		YR(NR)	Y-coordinate of last computation

NOTES:

(1) Computations at each offset point are made at all the high depths. The origin of the coordinates is at nodal point 1; i.e., model of slab 1. Refer to the nodal numbers shown in Figure 2 of Report 2 if stresses and deflections are to be computed. The first location is directly under node 1, the second location is midpoint between nodes 5

and 8, and the third location is at the center of element 13. The input values of XR(1) , YR(1) , XR(2) , YR(2) , XR(3) , and YR(3) should then be 0, 0, 135, 90, -135, and -135. Note that nodes 1, 16, 21, and 36 share the same location.

PART V: EXAMPLE PROBLEMS

34. In this Part, the input data of four example problems are presented. Printouts of the computer outputs for the example problems are also presented and explained.

Example Problem 1: A Two-Slab Pavement System on Elastic Solids

35. Figure 2 shows the finite element grid of a two-slab pavement. The nodes and elements are numbered consecutively from bottom to top and then from left to right. The input data consist of the following information:

- a. The concrete slab is 8 in. thick with a Young's modulus of 4,000,000 psi and a Poisson's ratio of 0.15. The elastic subgrade soil has a Young's modulus of 10,000 psi and a Poisson's ratio of 0.4.
- b. The pavement is subjected to a uniformly distributed square load applied at the center of the slabs. The option of symmetry with respect to the X-axis is used.
- c. Dowel bars are not used in the transverse joint connecting the two slabs. The joint is assumed to have a certain percentage of efficiency in shear transfer across the joint.
- d. The input data for Example problem 1 are given in Table 2. The joint efficiency in this particular case is 100 percent; i.e., the deflections at both sides of the joint are equal.

36. Table 3 shows the printout of the computer output for Example problem 1. The printout is in many places self-explanatory. For convenience of explanation, entry numbers are used where explanations are needed.

Entry 1

37. Because the option of symmetry with respect to the X-axis was used, the parameter NSYM was input as 3. Because the option of shear transfer across the joint is used, the parameter LTR was input as 0. The half bandwidth NB = 21 was the minimum required. In this

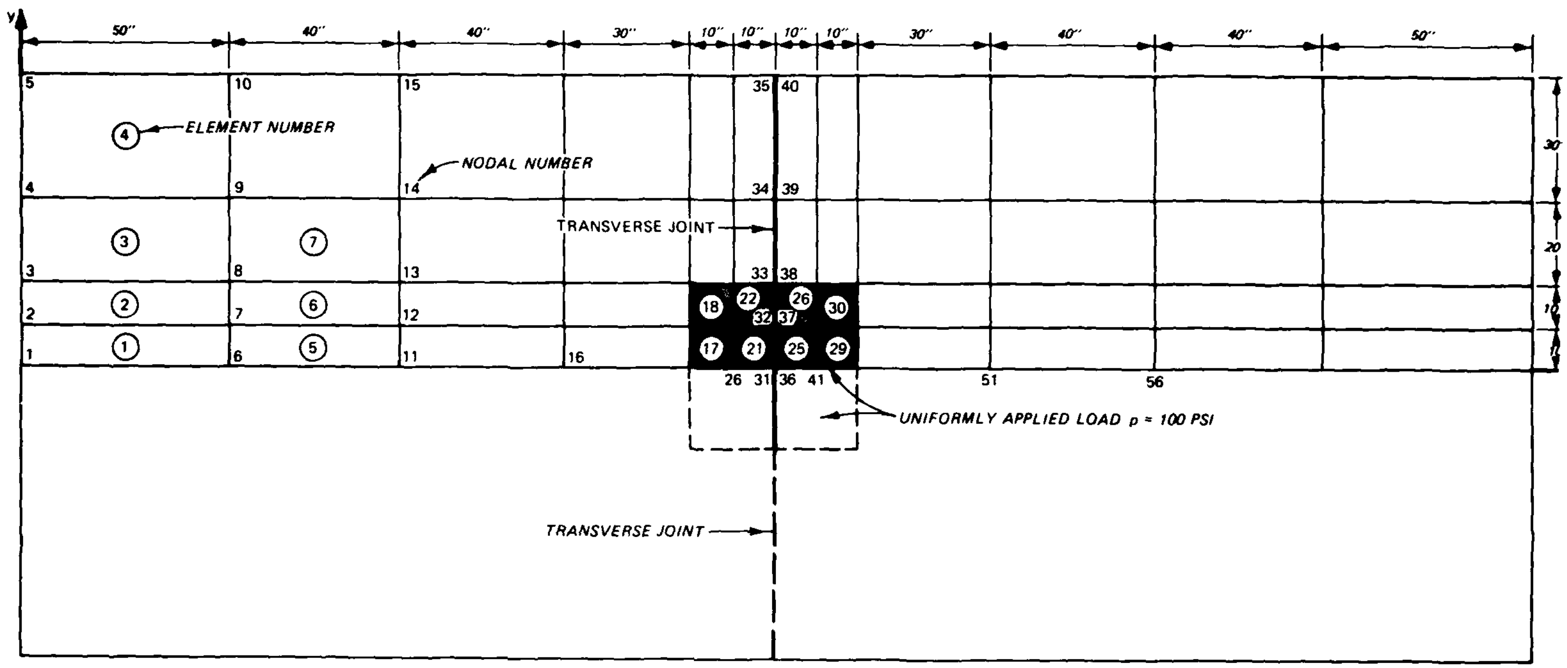

Figure 2. Finite element layout and loading conditions for Example problem 1

Table 2. Example Problem 1, Input Data for a Two-Slab Pavement on an Elastic Solid, 100 Percent Shear Transfer Across the Joint

GENERAL PURPOSE DATA FORM

PROGRAM | DATE

REQUESTED BY | PREPARED BY | CHECKED BY | PAGE | OF

```
    1
  2-slab pavement, 100 percent shear transfer across the joint, elastic half-space
    2 0.15   8.  4000000.     10000. 0.4    3    0    0    0   21    0
    7    7    5    1   16    1
   31   32   33   34   35   36   37   38   39   40   11   16   26   41   51   56
        0.       50.       90.      130.      160.      170.      180.      180.
     190.      200.      230.      270.      310.      360.
        0.       10.       20.       40.       70.
    0    0    8  300  300    2    0    0
        0.       50.      0.01     0.001       0.1        1.
   32   33
```

```
    40000.00
   17   18   21   22   25   26   29   30
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
```

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Table 3. Printout of Computer Output for Example Problem 1, Elastic Solid, and 100 Percent Shear Transfer Across the Joint, Constant Relaxation Factor RFJ

```
                    FINITE ELEMENT ANALYSIS OF CONCRETE SLABS

              NO. OF SLABS =           2  POISSON RATIO OF CONCRETE=    0.1500       THICKNESS OF CONCRETE=     8.0000
Entry 1  MODULUS OF CONCRETE= 0.400E 07        MODULUS OF SUBGRADE= 0.100E 05   POISSON RATIO OF SUBGRADE=   0.4000

   NSYM=          3      NPROB=          1    NSTERE=        0     NPUNCH=        0       LTR=          0
    NX1=          7       NX2=           7        NV=        5     NCYCLE=        1     NOTCON=         0      NB=       21
   NLA=           1

  STRESSES AT THE FOLLOWING NODES ARE TO BE PRINTED=
     11       15       26       31       32       33       34       35       36       37
     38       39       40       41       51       56
  VALUES OF X ARE=
     0.       50.000   90.000   130.000   160.000   170.000   180.000   180.000   190.000   200.000
   230.000   270.000  310.000   360.000

  VALUES OF Y ARE=
     0.       10.000   20.000    40.000    70.000
     EXP UNDERFLO  AT LOCATION   077173
     EXP UNDERFLO  AT LOCATION   077173
     EXP UNDERFLO  AT LOCATION   077173
     EXP UNDERFLO  AT LOCATION   077173
     EXP UNDERFLO  AT LOCATION   077173    can be ignored
     EXP UNDERFLO  AT LOCATION   077173
     EXP UNDERFLO  AT LOCATION   077173
     EXP UNDERFLO  AT LOCATION   077173
     EXP UNDERFLO  AT LOCATION   077173


    NGAP=     0       NTEP=     0       NLOAD=     8          ICL=  300        NCK=     2         NWT=     0
    TEMP=    0.          Q=   50.00000    RFJ=   0.10000      DFL=   0.01000    DELF=  0.00100     ICLF=  300
    EFF=1.000        IGNOR=   1

    THE FOLLOWING NODES ARE USED TO CHECK CONVERGENCE=
Entry 2  32          33

    AMOUNT OF INITIAL CURLING AND GAP AT THE NODES IS=
     1    0.       2    0.       3    0.       4    0.        5    0.       6    0.       7    0.
     8    0.       9    0.      10    0.      11    0.       12    0.      13    0.      14    0.
    15    0.      16    0.      17    0.      18    0.       19    0.      20    0.      21    0.
    22    0.      23    0.      24    0.      25    0.       26    0.      27    0.      28    0.
    29    0.      30    0.      31    0.      32    0.       33    0.      34    0.      35    0.
    36    0.      37    0.      38    0.      39    0.       40    0.      41    0.      42    0.
    43    0.      44    0.      45    0.      46    0.       47    0.      48    0.      49    0.
    50    0.      51    0.      52    0.      53    0.       54    0.      55    0.      56    0.
    57    0.      58    0.      59    0.      60    0.       61    0.      62    0.      63    0.
    64    0.      65    0.      66    0.      67    0.       68    0.      69    0.      70    0.

   WHEEL LOADS ARE APPLIED ON THE FOLLOWING ELEMENTS AND COORDINATES=
              17        -1.00000        1.00000       -1.00000        1.00000
              18        -1.00000        1.00000       -1.00000        1.00000
              21        -1.00000        1.00000       -1.00000        1.00000
              22        -1.00000        1.00000       -1.00000        1.00000
              25        -1.00000        1.00000       -1.00000        1.00000
              26        -1.00000        1.00000       -1.00000        1.00000
              29        -1.00000        1.00000       -1.00000        1.00000
              30        -1.00000        1.00000       -1.00000        1.00000
Entry 3

     JC=           1
```

(Continued)   (Sheet 1 of 3)

Table 3 (Continued)

THE DIFFERENCES BETWEEN TWO ITERATIONS ARE
TABULATED BELOW,THE LAST INTEGER + REAL NUMBERS BEING THE ITERA TION NUMBER AND THE RELAXATION FACTOR RESPECTIVELY

NODE	DEFLECTION AND DEFLECTION DIFFERENCE						
32	0.855373E-01	0.393117E-01	33	0.720804E-01	0.352218E-01	1	0.100000E 01
32	0.116773E 00	0.302159E-01	33	0.101692E 00	0.296112E-01	2	0.100000E 01
32	0.123252E 00	0.124889E-01	33	0.114519E 00	0.128278E-01	3	0.100000E 01
32	0.127356E 00	0.459438E-02	33	0.119587E 00	0.506736E-02	4	0.100000E 01
32	0.126391E 00	0.534367E-03	33	0.120564E 00	0.977618E-03	5	0.100000E 01
32	0.126736E 00	-0.162479E-02	33	0.119323E 00	-0.124190E-02	6	0.100000E 01
32	0.124031E 00	-0.270469E-02	33	0.116940E 00	-0.238241E-02	7	0.100000E 01
32	0.120919E 00	-0.314202E-02	33	0.114066E 00	-0.288392E-02	8	0.100000E 01
32	0.117720E 00	-0.319888E-02	33	0.111089E 00	-0.297733E-02	9	0.100000E 01
32	0.114680E 00	-0.304049E-02	33	0.108231E 00	-0.285831E-02	10	0.100000E 01
32	0.111959E 00	-0.277046E-02	33	0.105609E 00	-0.262137E-02	11	0.100000E 01
32	0.109456E 00	-0.245397E-02	33	0.103277E 00	-0.233226E-02	12	0.100000E 01
32	0.107325E 00	-0.213054E-02	33	0.101245E 00	-0.203147E-02	13	0.100000E 01
32	0.105513E 00	-0.182190E-02	33	0.995040E-01	-0.174145E-02	14	0.100000E 01
32	0.103953E 00	-0.154043E-02	33	0.980288E-01	-0.147523E-02	15	0.100000E 01
32	0.102672E 00	-0.129030E-02	33	0.967912E-01	-0.128756E-02	16	0.100000E 01
32	0.101599E 00	-0.107317E-02	33	0.957607E-01	-0.103056E-02	17	0.100000E 01
32	0.100712E 00	-0.887319E-03	33	0.949077E-01	-0.852927E-03	18	0.100000E 01
32	0.999815E-01	-0.730392E-03	33	0.942051E-01	-0.702686E-03	19	0.100000E 01
32	0.993829E-01	-0.598527E-03	33	0.936288E-01	-0.576225E-03	20	0.100000E 01
32	0.989937E-01	-0.489295E-03	33	0.931575E-01	-0.471326E-03	21	0.100000E 01
32	0.984952E-01	-0.398412E-03	33	0.927735E-01	-0.388982E-03	22	0.100000E 01
32	0.981716E-01	-0.323640E-03	33	0.924615E-01	-0.312050E-03	23	0.100000E 01
32	0.979[illegible]E-01	-0.262087E-03	33	0.922087E-01	-0.252764E-03	24	0.100000E 01
32	0.976979E-01	-0.212526E-03	33	0.920037E-01	-0.205048E-03	25	0.100000E 01
32	0.975255E-01	-0.171506E-03	33	0.918381E-01	-0.165521E-03	26	0.100000E 01
32	0.973867E-01	-0.136759E-03	33	0.917042E-01	-0.138912E-03	27	0.100000E 01
32	0.972754E-01	-0.111661E-03	33	0.915964E-01	-0.107636E-03	28	0.100000E 01
32	0.971851E-01	-0.895322E-04	33	0.915096E-01	-0.868430E-04	29	0.100000E 01

Entry & IC= 29

NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION
1	0.111459E-01	2	0.115307E-01	3	0.120774E-01	4	0.108709E-01
5	0.103257E-01	6	0.164351E-01	7	0.163660E-01	8	0.161040E-01
9	0.157763E-01	10	0.135181E-01	11	0.259962E-01	12	0.259768E-01
13	0.252067E-01	14	0.229879E-01	15	0.179197E-01	16	0.481092E-01
17	0.475319E-01	18	0.457063E-01	19	0.394309E-01	20	0.369337E-01
21	0.772174E-01	22	0.758723E-01	23	0.718941E-01	24	0.991498E-01
25	0.386632E-01	26	0.862684E-01	27	0.865234E-01	28	0.818480E-01
29	0.571276E-01	30	0.436583E-01	31	0.992210E-01	32	0.971081E-01
33	0.915095E-01	34	0.747081E-01	35	0.490195E-01	36	0.986680E-01
37	0.964411E-01	38	0.907905E-01	39	0.740660E-01	40	0.485860E-01
41	0.877032E-01	42	0.859597E-01	43	0.811073E-01	44	0.685490E-01
45	0.433031E-01	46	0.769114E-01	47	0.754809E-01	48	0.718620E-01
49	0.591123E-01	50	0.384359E-01	51	0.480965E-01	52	0.478893E-01
53	0.454060E-01	54	0.373341E-01	55	0.269140E-01	56	0.260074E-01
57	0.251054E-01	58	0.252195E-01	59	0.250055E-01	60	0.179500E-01
61	0.164531E-01	62	0.163640E-01	63	0.161817E-01	64	0.159957E-01
65	0.133270E-01	66	0.115508E-01	67	0.111856E-01	68	0.110082E-01
69	0.105751E-01	70	0.103287E-01				

(Continued) (Sheet 2 of 3)

Table 3 (Concluded)

Entry 5

NODE	STRESS X	STRESS Y	STRESS XY	MAJOR	MINOR	SHEAR
11	-0.112693E 03	0.471606E 02	0.150837E 01	-0.112467E 03	0.471[illegible] 02	0.798[illegible] 02
16	-0.216627E 03	0.173729E 03	-0.988936E 00	-0.216629E 03	0.173[illegible] 03	0.195[illegible] 03
26	0.131169E 03	0.599269E 03	0.841949E 00	0.131140E 03	[illegible] 03	[illegible] 03
31	0.	[illegible] 03	0.	0.	[illegible]	[illegible]
32	0.	0.618734E 03	0.	0.	[illegible]	[illegible]
33	0.	0.388078E 03	0.	0.	[illegible]	[illegible]
34	0.	-0.682764E 02	0.	-0.682764E 02	0.	[illegible] 02
35	0.	0.	0.	0.	0.	0.
36	0.	0.666847E 03	0.	0.	[illegible]	[illegible]
37	0.	[illegible] 03	0.	0.	[illegible]	[illegible]
38	0.	[illegible] 03	0.	0.	[illegible]	[illegible]
39	0.	-0.800442E 02	0.	-0.800442E 02	0.	[illegible] 02
40	0.	0.	0.	0.	0.	0.
41	0.135904E 03	0.599828E 03	-0.544192E 00	0.135[illegible] 03	0.599[illegible] 03	0.28[illegible] 03
51	-0.213297E 03	0.173543E 03	0.990630E 00	-0.21[illegible] 03	0.173[illegible] 03	[illegible] 03
56	-0.111686E 03	0.47[illegible] 02	-0.150394E 01	-0.11[illegible] 03	0.471[illegible] 02	0.79[illegible] 02

32 0.97012E-05 -0.728968E-04 33 0.954892E-01 -0.708484E-04 88 0.100000 00
ICe 34

NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION
1	0.111467E-01	2	0.113358E-01	3	0.120[illegible]	4	[illegible]-01
5	0.103263E-01	6	0.104372E-01	7	0.153[illegible]	8	[illegible]-01
9	0.193844E-01	10	0.139181E-01	11	0.2997[illegible]	12	[illegible]-01
13	0.252084E-01	14	0.229901E-01	15	0.1798[illegible]	16	[illegible]-01
17	0.475219E-01	18	0.454970E-01	19	0.3948[illegible]	20	[illegible]-01
21	0.772782E-01	22	0.758383E-01	23	0.7281[illegible]	24	[illegible]-01
25	0.346435E-01	26	0.882111E-01	27	0.8845[illegible]	28	[illegible]-01
29	0.669811E-01	30	0.436200E-01	31	0.99147[illegible]	32	[illegible]-01
33	0.914392E-01	34	0.744494E-01	35	0.40969[illegible]	36	[illegible]-01
37	0.945155E-01	38	0.906634E-01	39	0.74160[illegible]	40	[illegible]-01
41	0.877573E-01	42	0.860099E-01	43	0.82141[illegible]	44	[illegible]-01
45	0.433309E-01	46	0.769523E-01	47	0.755313E-01	48	[illegible]-01
49	0.591468E-01	50	0.384589E-01	51	0.480878E-01	52	[illegible]-01
53	0.496165E-01	54	0.398482E-01	55	0.289268E-01	56	[illegible]-01
57	0.298077E-01	58	0.729147E-01	59	0.280048E-01	60	[illegible]-01
61	0.164516E-01	62	0.168826E-01	63	0.181803E-01	64	[illegible]-01
65	0.185257E-01	66	0.111586E-01	67	0.121854E-01	68	0.110[illegible]-01
69	0.188750E-01	70	0.108287E-01				

Entry 6

NODE	STRESS X	STRESS Y	STRESS XY	MAJOR	MINOR	SHEAR
11	-0.112370E 03	0.471582E 02	0.150793E 01	-0.112384E 03	0.471[illegible] 02	0.797783E 02
16	-0.216298E 03	0.173718E 03	-0.988754E 00	-0.216360E 03	0.173[illegible] 03	0.19[illegible] 03
26	0.131637E 03	0.599144E 03	0.942117E 00	0.131630E 03	0.599[illegible] 03	0.283[illegible] 03
31	0.	0.860519E 03	0.	0.	[illegible] 03	0.384[illegible] 03
32	0.	0.618462E 03	0.	0.	[illegible] 03	0.309[illegible] 03
33	0.	0.387090E 03	0.	0.	0.387[illegible] 03	[illegible] 03
34	0.	-0.682524E 02	0.	-0.68[illegible] 02	0.	0.341263E 02
35	0.	0.	0.	0.	0.	0.
36	0.	0.667143E 03	0.	0.	0.667143E 03	0.333572E 03
37	0.	0.816297E 03	0.	0.	0.816[illegible] 03	[illegible] 03
38	0.	0.356470E 03	0.	0.	0.356[illegible] 03	[illegible] 03
39	0.	-0.800668E 02	0.	-0.800668E 02	0.	[illegible] 02
40	0.	0.	0.	0.	0.	0.
41	0.135435E 03	0.597974E 03	-0.544302E 00	0.135435E 03	0.597975E 03	0.231270E 03
51	-0.213628E 03	0.173562E 03	0.990595E 00	-0.213631E 03	0.173[illegible] 03	0.193597E 03
56	-0.111690E 03	0.471463E 02	-0.150441E 01	-0.111705E 03	0.471[illegible] 02	0.794[illegible] 02

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special case, the relaxation factor RFJ = 0.1 is fixed as a constant by setting the parameter IGNOR = 1 .

Entry 2

38. The initial curling and gap at all nodes are 0 because the temperature and the gap are not considered in the computation.

Entry 3

39. Since NCYCLE = 1 , i.e., the slab is assumed to be in contact with the subgrade all the time, NIC will not be iterated greater than 1.

Entry 4

40. The deflections at each node are tabulated whether convergence requirements are met. Positive deflection indicates downward movement.

Entry 5

41. The stress components at preselected points are printed. Positive stress indicates that the slab has compression at the top and tension at the bottom and negative stress indicates compression at the bottom and tension at the top. The symbols of STRESS XY, MAJOR, MINRO, and SHEAR stand for shear stress, major principal stress, minor principal stress, and maximum shear stress, respectively.

Entry 6

42. The stresses and displacements are computed for one more iteration for inspection of convergence by the user. When the solution correctly converges, the differences in the computed results between two iterations should be very insignificant. Otherwise, the solution is not convergent.

43. Because of the existence of symmetry with respect to the Y-axis along the transverse joint, the stresses and deflections at corresponding points in the left and right sides should be equal. Printed results in Entry 6 show that the stresses and deflections at nodal points 11, 16, 26, 31, 32, 33, 34, and 35 are very close to those computed in points 56, 51, 41, 36, 37, 38, 39, and 40, respectively.

44. The following two special features in Example problem 1 should be pointed out:

a. Because the slabs are symmetrically loaded, the use of a shear transfer across the joint less than 100 percent will produce meaningless results.

b. While the system is symmetrically loaded, the use of the symmetry option with respect to both the X- and Y-axis is wrong because the axis of symmetry in the Y-direction lies on the joint which is formidable.

45. The results shown in Table 3 were computed with the relaxation factor RFJ = 0.1 .

46. Table 4 is another printout of the computer output with the same conditions as those shown in Example problem 1, except that the efficiency of shear transfer across the joint is assumed to be 80 percent and the loads applied at the right slab are removed. Eighty percent shear transfer denotes that the deflections at the unloaded (or less heavily loaded) slab are 80 percent of the loaded (or more heavily loaded) slabs. The computed deflections at nodes 31 and 36 indicate that the computed results are correct. It should be noted that since 80 percent shear transfer is assumed, meaningless results will be computed if the slabs are symmetrically loaded with respect to the transverse joint.

Example Problem 2: A Two-Slab Pavement System on Elastic Solids, Dowel Bars Across the Joint

47. The same configuration of pavements used in Example problem 1 (Figure 2) is used in this one. Dowel bars are used across the transverse joint; the bars have a diameter of 1 in. and are placed 12 in. apart. The input data and the printout of the computer output are given in Tables 5 and 6, respectively. When dowel bars are used, the options LTR and EFF are both input as 1. The computed results show that the stress σ_y and deflections in the loaded slab are greater than those in the unloaded slab.

Example Problem 3: A Two-Slab Pavement System on Layered Elastic Solids

48. Table 7 shows the input data for a two-slab pavement system

Table 4. Computer Output for Example Problem 1, Elastic Solid and 80 Percent Shear Transfer Across the Joint, One Loaded Slab

```
                FINITE ELEMENT ANALYSIS OF CONCRETE SLABS

          NO. OF SLABS =          2  POISSON RATIO OF CONCRETE=   0.1900     THICKNESS OF CONCRETE=    6.0000
     MODULUS OF CONCRETE= 0.400E 07        MODULUS OF SUBGRADE= 0.200E 05  POISSON RATIO OF SUBGRADE=  0.4000

   NSYM=          3     NPROB=        1    NSTRES=        0     NPUNCH=       0        TB=        0
    NX1=          7      NX2=         7       NY=         5     NCYCLE=       1     NOTCON=        0      NB=       21
    NLA=          1

  STRESSES AT THE FOLLOWING NODES ARE TO BE PRINTED=
     11        15        26        31        32        33        34        35        36        37
     38        39        40        41        51        56
 VALUES OF X ARE=
     0.       50.000    90.000   130.000   160.000   170.000   180.000   180.000   190.000   200.000
  230.000    270.000   310.000   360.000

 VALUES OF Y ARE=
     0.       10.000    20.000    40.000    70.000
    EXP UNDERFLO  AT LOCATION    077173
    EXP UNDERFLO  AT LOCATION    077173
    EXP UNDERFLO  AT LOCATION    077173
    EXP UNDERFLO  AT LOCATION    077173     Can be ignored
    EXP UNDERFLO  AT LOCATION    077173
    EXP UNDERFLO  AT LOCATION    077173
    EXP UNDERFLO  AT LOCATION    077173
    EXP UNDERFLO  AT LOCATION    077173
    EXP UNDERFLO  AT LOCATION    077173


   NGAP=     0        NTEMP=      0       NLOAD=      4          ICL=   300        NCK=      2        NWT=     0
   TEMP=   0.             Q=   50.00000    WFJ=   0.10000         DFL=   0.01000    DELF=   0.00100   ICLF=   300
    EFF=0.800          IGNOR=      1

   THE FOLLOWING NODES ARE USED TO CHECK CONVERGENCE=
      32          33

   AMOUNT OF INITIAL CURLING AND GAP AT THE NODES IS=
  1   0.          2   0.          3   0.          4   0.          5   0.          6   0.          7   0.
  8   0.          9   0.         10   0.         11   0.         12   0.         13   0.         14   0.
 15   0.         16   0.         17   0.         18   0.         19   0.         20   0.         21   0.
 22   0.         23   0.         24   0.         25   0.         26   0.         27   0.         28   0.
 29   0.         30   0.         31   0.         32   0.         33   0.         34   0.         35   0.
 36   0.         37   0.         38   0.         39   0.         40   0.         41   0.         42   0.
 43   0.         44   0.         45   0.         46   0.         47   0.         48   0.         49   0.
 50   0.         51   0.         52   0.         53   0.         54   0.         55   0.         56   0.
 57   0.         58   0.         59   0.         60   0.         61   0.         62   0.         63   0.
 64   0.         65   0.         66   0.         67   0.         68   0.         69   0.         70   0.

  WHEEL LOADS ARE APPLIED ON THE FOLLOWING ELEMENTS AND COORDINATES=
          17       -1.00000        1.00000       -1.00000        1.00000
          18       -1.00000        1.00000       -1.00000        1.00000
          21       -1.00000        1.00000       -1.00000        1.00000
          22       -1.00000        1.00000       -1.00000        1.00000

   NIC=          1
```

(Continued)

(Sheet 1 of 3)

Table 4 (Continued)

THE DIFFERENCES BETWEEN THE ITERATIONS ARE
TABULATED BELOW THE LAST INTEGER + REAL NUMBERS BEING THE ITERA TION NUMBER AND THE RELAXATION FACTOR RESPECTIVELY

NODE	DEFLECTION AND DEFLECTION DIFFERENCE						
32	0.451799E-01	-0.106972E-02	33	0.359877E-01	-0.470897E-03	1	0.100000E 00
32	0.559545E-01	0.157768E-01	33	0.514249E-01	0.154371E-01	2	0.100000E 00
32	0.630574E-01	0.710097E-02	33	0.586129E-01	0.710808E-02	3	0.100000E 00
32	0.662146E-01	0.315715E-02	33	0.619351E-01	0.332211E-02	4	0.100000E 00
32	0.672034E-01	0.134879E-02	33	0.631500E-01	0.121492E-02	5	0.100000E 00
32	0.671214E-01	-0.142027E-03	33	0.631579E-01	0.788365E-05	6	0.100000E 00
32	0.663202E-01	-0.801164E-03	33	0.624874E-01	-0.670485E-03	7	0.100000E 00
32	0.651066E-01	-0.113398E-02	33	0.614660E-01	-0.102138E-02	8	0.100000E 00
32	0.639765E-01	-0.126311E-02	33	0.602983E-01	-0.116771E-02	9	0.100000E 00
32	0.626535E-01	-0.126997E-02	33	0.591089E-01	-0.118936E-02	10	0.100000E 00
32	0.614476E-01	-0.120576E-02	33	0.579707E-01	-0.118018E-02	11	0.100000E 00
32	0.603430E-01	-0.110460E-02	33	0.569229E-01	-0.104786E-02	12	0.100000E 00
32	0.593559E-01	-0.987093E-03	33	0.559832E-01	-0.939731E-03	13	0.100000E 00
32	0.584893E-01	-0.866585E-03	33	0.551560E-01	-0.827166E-03	14	0.100000E 00
32	0.577386E-01	-0.750775E-03	33	0.544379E-01	-0.718053E-03	15	0.100000E 00
32	0.570943E-01	-0.643796E-03	33	0.538213E-01	-0.616680E-03	16	0.100000E 00
32	0.565466E-01	-0.547729E-03	33	0.532958E-01	-0.525485E-03	17	0.100000E 00
32	0.560835E-01	-0.463365E-03	33	0.528510E-01	-0.444809E-03	18	0.100000E 00
32	0.556937E-01	-0.389776E-03	33	0.524765E-01	-0.374483E-03	19	0.100000E 00
32	0.553676E-01	-0.326045E-03	33	0.521624E-01	-0.314024E-03	20	0.100000E 00
32	0.550975E-01	-0.272591E-03	33	0.519003E-01	-0.262190E-03	21	0.100000E 00
32	0.548674E-01	-0.227842E-03	33	0.516818E-01	-0.218493E-03	22	0.100000E 00
32	0.546786E-01	-0.188633E-03	33	0.515002E-01	-0.181574E-03	23	0.100000E 00
32	0.545225E-01	-0.156284E-03	33	0.513497E-01	-0.150506E-03	24	0.100000E 00
32	0.543930E-01	-0.129502E-03	33	0.512250E-01	-0.124724E-03	25	0.100000E 00
32	0.542860E-01	-0.106947E-03	33	0.511219E-01	-0.103044E-03	26	0.100000E 00
32	0.541977E-01	-0.883002E-04	33	0.510368E-01	-0.851452E-04	27	0.100000E 00
32	0.541248E-01	-0.728765E-04	33	0.509665E-01	-0.702315E-04	28	0.100000E 00
32	0.540648E-01	-0.600591E-04	33	0.509087E-01	-0.578798E-04	29	0.100000E 00
32	0.540153E-01	-0.494877E-04	33	0.508610E-01	-0.477065E-04	30	0.100000E 00

ICO 30

NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION
1	0.586417E-02	2	0.585481E-02	3	0.582808E-02	4	0.569463E-02
5	0.535681E-02	6	0.902292E-02	7	0.897834E-02	8	0.887918E-02
9	0.633979E-02	10	0.713492E-02	11	0.149871E-01	12	0.147985E-01
13	0.144061E-01	14	0.129580E-01	15	0.967029E-02	16	0.268802E-01
17	0.280523E-01	18	0.268288E-01	19	0.226896E-01	20	0.148036E-01
21	0.450674E-01	22	0.441228E-01	23	0.415178E-01	24	0.337240E-01
25	0.513001E-01	26	0.504014E-01	27	0.493280E-01	28	0.463967E-01
29	0.376319E-01	30	0.241251E-01	31	0.551467E-01	32	0.548153E-01
33	0.506613E-01	34	0.419281E-01	35	0.272458E-01	36	0.638904E-01
37	0.427987E-01	38	0.402897E-01	39	0.328845E-01	40	0.215177E-01
41	0.375623E-01	42	0.369082E-01	43	0.350215E-01	44	0.291973E-01
45	0.193561E-01	46	0.320478E-01	47	0.315494E-01	48	0.302433E-01
49	0.255579E-01	50	0.172496E-01	51	0.196312E-01	52	0.194268E-01
53	0.188293E-01	54	0.166833E-01	55	0.121206E-01	56	0.116781E-01
57	0.110075E-01	58	0.108073E-01	59	0.100441E-01	60	0.825809E-02
61	0.742145E-02	62	0.739695E-02	63	0.782961E-02	64	0.788746E-02
65	0.538389E-02	66	0.528442E-02	67	0.527858E-02	68	0.525796E-02
69	0.517861E-02	70	0.497092E-02				

NODE	STRESS X	STRESS Y	STRESS XY	MAJOR	MINOR	SHEAR
11	-0.698543E 02	0.317289E 02	0.983987E 00	-0.698648E 02	0.317389E 02	0.508016E 02
16	-0.122695E 03	0.121448E 03	-0.162248E [illegible]	-0.122656E 03	0.121459E 03	0.122097E 03
26	[illegible]	0.384117E 03	0.855839E 00	0.190325E 03	0.384131E 03	0.929083E 02
31	0.	0.371232E 03	0.	0.	0.371232E 03	0.185616E 03

(Continued) (Sheet 2 of 3)

Table 4 (Concluded)

32	0.	0.342393E 03	0.	0.	0.342393E 03	0.171196E 03
33	0.	0.199421E 03	0.	0.	0.199421E 03	0.99[illegible]E 02
34	0.	-0.348561E 02	0.	-0.348561E 02	0.	0.174[illegible]E 02
35	0.	0.	0.	0.	0.	0.
36	0.	0.297096E 03	0.	0.	0.297096E 03	0.[illegible]E 03
37	0.	0.274983E 03	0.	0.	0.274983E 03	0.[illegible]E 03
38	0.	0.157773E 03	0.	0.	0.157773E 03	0.[illegible]E 02
39	0.	-0.333033E 02	0.	-0.333033E 02	0.	0.[illegible]E 02
40	0.	0.	0.	0.	0.	0.
41	-0.647914E 02	0.214432E 03	0.312539E 00	-0.[illegible]E 02	0.214[illegible]E 03	0.[illegible]E 03
51	-0.923154E 02	0.521906E 02	-0.432844E 00	-0.92[illegible]E 02	0.521[illegible]E 02	0.72[illegible]E 02
56	-0.421748E 02	0.154251E 02	-0.522146E 00	-0.421795E 02	0.1542[illegible]E 02	0.28[illegible]E 02

32 0.539746E-01 -0.407086E-04 33 0.508217E-01 -0.392492E-04 34 0.100000E 01

TC# 31

NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION
1	0.544454E-02	2	0.585917E-02	3	0.582243E-02	4	0.[illegible]E-02
5	0.535677E-02	6	0.902480E-02	7	0.897942E-02	8	0.[illegible]E-02
9	0.634085E-02	10	0.713597E-02	11	0.149278E-01	12	0.[illegible]E-01
13	0.144069E-01	14	0.129541E-01	15	0.980018E-02	16	0.[illegible]E-01
17	0.240469E-01	18	0.268214E-01	19	0.226855E-01	20	0.[illegible]E-01
21	0.450452E-01	22	0.441009E-01	23	0.414767E-01	24	0.[illegible]E-01
25	0.212083E-01	26	0.503784E-01	27	0.492774E-01	28	0.[illegible]E-01
29	0.376057E-01	30	0.241063E-01	31	0.551055E-01	32	0.[illegible]E-01
33	0.508217E-01	34	0.414084E-01	35	0.272105E-01	36	0.437[illegible]E-01
37	0.428399E-01	38	0.403296E-01	39	0.328990E-01	40	0.[illegible]E-01
41	0.376141E-01	42	0.369374E-01	43	0.390517E-01	44	0.[illegible]E-01
45	0.193755E-01	46	0.320786E-01	47	0.315918E-01	48	0.[illegible]E-01
49	0.255765E-01	50	0.172623E-01	51	0.196875E-01	52	0.[illegible]E-01
53	0.188357E-01	54	0.166078E-01	55	0.121219E-01	56	0.[illegible]E-01
57	0.110071E-01	58	0.108069E-01	59	0.100435E-01	60	0.[illegible]E-02
61	0.742361E-02	62	0.739611E-02	63	0.732470E-02	64	0.[illegible]E-02
65	0.638308E-02	66	0.528425E-02	67	0.527041E-02	68	0.[illegible]E-02
69	0.517347E-02	70	0.497084E-02				

$\frac{0.0437}{0.0551} \approx 0.80$

NODE	STRESS X	STRESS Y	STRESS XY	MAJOR	MINOR	SHEAR
11	-0.698059E 02	0.317276E 02	0.983716E 00	-0.698184E 02	0.317[illegible]E 02	0.[illegible]E 02
16	-0.122463E 03	0.121436E 03	-0.162265E 01	-0.122474E 03	0.121446E 03	0.[illegible]E 03
26	0.198586E 03	0.384036E 03	0.855913E 00	0.198582E 03	0.384040E 03	0.[illegible]E 02
31	0.	0.371058E 03	0.	0.	0.371058E 03	0.[illegible]E 03
32	0.	0.342235E 03	0.	0.	0.342235E 03	0.171[illegible]E 03
33	0.	0.199307E 03	0.	0.	0.199307E 03	0.99[illegible]E 02
34	0.	-0.348430E 02	0.	-0.348430E 02	0.	0.174[illegible]E 02
35	0.	0.	0.	0.	0.	0.
36	0.	0.297270E 03	0.	0.	0.297270E 03	0.[illegible]E 03
37	0.	0.275142E 03	0.	0.	0.275142E 03	0.[illegible]E 03
38	0.	0.157877E 03	0.	0.	0.157877E 03	0.[illegible]E 02
39	0.	-0.333167E 02	0.	-0.333167E 02	0.	0.[illegible]E 02
40	0.	0.	0.	0.	0.	0.
41	-0.650504E 02	0.214521E 03	0.312429E 00	-0.650507E 02	0.214[illegible]E 03	0.[illegible]E 03
51	-0.924993E 02	0.522013E 02	-0.433028E 00	-0.925020E 02	0.522[illegible]E 02	0.72[illegible]E 02
56	-0.422217E 02	0.154257E 02	-0.522432E 00	-0.422264E 02	0.154[illegible]E 02	0.28[illegible]E 02

(Sheet 3 of 3)

Table 5. Example Problem 2, Input Data for a Two-Slab Pavement on an Elastic Solid, 1-in. Dowel Bars Across the Joint

GENERAL PURPOSE DATA FORM

PROGRAM | DATE
REQUESTED BY | PREPARED BY | CHECKED BY | PAGE OF

```
    1
  2-slab pavement, 1-in. dowel bars, elastic solid.
    2 0.15    8.    4000000.    10000.  0.4    3    0    0    0   21    1
    7    7    5    1   16    1
   31   32   33   34   35   36   37   38   39   40   11   16   26   41   51   56
        0.       50.       90.      130.      160.      170.      180.      180.
      190.      200.      230.      270.      310.      360.
        0.       10.       20.       40.       70.
    0    0    4  300  300    2    0    0
        0.       50.      0.01     0.001      0.01        1.
   32   33
```

```
        1.       12.   0.03125      0.15 30000000.  1500000.
   5000.00
   17   18   21   22
        0.        1.        0.        1.
        0.        1.       -1.        0.
        0.        1.        0.        1.
        0.        1.       -1.        0.
```

WES FORM 1233 EDITION OF SEP 62 WILL BE USED UNTIL EXHAUSTED

Table 6. Computer Output for Example Problem 2, Elastic Half-Space and 1-in. Dowel Bars Across the Joint

```
FINITE ELEMENT ANALYSIS OF CONCRETE SLABS
         NO. OF SLABS =          2  POISSON RATIO OF CONCRETE=    0.1500      THICKNESS OF CONCRETE=    8.0000
      MODULUS OF CONCRETE= 0.400E 07        MODULUS OF SUBGRADE= 0.800E 05  POISSON RATIO OF SUBGRADE=   0.4000

NSYM=        3     NBRUB=        1     NSTERS=        0     NPUNCH=        0     LTR=        1
NX1=         7     NX2=          7     NY=            5     NCYLE=         1     NOTCON=     0     NB=      21
NLS=         1

STRESSES AT THE FOLLOWING NODES ARE TO BE PRINTED=
   11      16      26      31      32      33      34      35      36      37
   38      39      40      41      51      56
VALUES OF X ARE=
 0.       50.000    90.000   130.000   160.000   170.000   180.000   180.000   190.000   200.000
230.000  270.000   310.000   360.000

VALUES OF Y ARE=
 0.       10.000    20.000    40.000    70.000
  EXP UNDERFLO  AT LOCATION     077113
  EXP UNDERFLO  AT LOCATION     077113
  EXP UNDERFLO  AT LOCATION     077113
  EXP UNDERFLO  AT LOCATION     077113
  EXP UNDERFLO  AT LOCATION     077113     Can be ignored
  EXP UNDERFLO  AT LOCATION     077113
  EXP UNDERFLO  AT LOCATION     077113
  EXP UNDERFLO  AT LOCATION     077113
  EXP UNDERFLO  AT LOCATION     077113


 NGAP=    8        NTEMP=    0        NLOAD=    4         ICL=  300        NCK=    2        NNT=    0
 TEMP=   0.          Q=  50.00000       RFJ=  1.00000       DEL=  0.01000    DELTA=  0.00100   ICLF=  300
  EFF=1.000       10.000   0.
 THE FOLLOWING NODES ARE USED TO CHECK CONVERGENCE=
    32       33

 SD=  3700000     BS=  12.00000     W=  0.03125     PRSG=  0.15000     YMSG 0.300E 08     DSM= 0.150E 07   (Dowel information)

 AMOUNT OF INITIAL CURLING AND GAP AT THE NODES IS=
  1   0.      2   0.      3   0.      4   0.      5   0.      6   0.      7   0.
  8   0.      9   0.     10   0.     11   0.     12   0.     13   0.     14   0.
 15   0.     16   0.     17   0.     18   0.     19   0.     20   0.     21   0.
 22   0.     23   0.     24   0.     25   0.     26   0.     27   0.     28   0.
 29   0.     30   0.     31   0.     32   0.     33   0.     34   0.     35   0.
 36   0.     37   0.     38   0.     39   0.     40   0.     41   0.     42   0.
 43   0.     44   0.     45   0.     46   0.     47   0.     48   0.     49   0.
 50   0.     51   0.     52   0.     53   0.     54   0.     55   0.     56   0.
 57   0.     58   0.     59   0.     60   0.     61   0.     62   0.     63   0.
 64   0.     65   0.     66   0.     67   0.     68   0.     69   0.     70   0.

 WHEEL LOADS ARE APPLIED ON THE FOLLOWING ELEMENTS AND COORDINATES=
        17        0.          1.00000      0.          1.00000
        18        0.          1.00000     -1.00000     0.
        21        0.          1.00000      0.          1.00000
        22        0.          1.00000     -1.00000     0.

 NIC=        1
```

(Continued)

(Sheet 1 of 5)

Table 6 (Continued)

THE DIFFERENCES BETWEEN TWO ITERATIONS ARE
TABULATED BELOW,THE LAST INTEGER + REAL NUMBERS BEING THE ITERATION NUMBER AND THE RELAXATION FACTOR,RESPECTIVELY

NODE	DEFLECTION AND DEFLECTION DIFFERENCE						
32	0.115595E-01	0.444576E-03	33	0.102642E-01	0.414415E-03	1	0.100000E 01
32	0.162313E-01	0.472846E-02	33	0.148240E-01	0.456283E-02	2	0.100000E 01
32	0.187339E-01	0.265264E-02	33	0.174361E-01	0.261207E-02	3	0.100000E 01
32	0.203841E-01	0.165210E-02	33	0.190708E-01	0.164076E-02	4	0.100000E 01
32	0.216357E-01	0.105164E-02	33	0.201317E-01	0.109284E-02	5	0.100000E 01
32	0.222934E-01	0.657718E-03	33	0.207954E-01	0.668701E-03	6	0.100000E 01
32	0.226521E-01	0.388659E-03	33	0.211946E-01	0.399200E-03	7	0.100000E 01
32	0.228844E-01	0.202704E-03	33	0.214053E-01	0.212738E-03	8	0.100000E 01
32	0.229598E-01	0.740234E-04	33	0.214902E-01	0.849082E-04	9	0.100000E 01
32	0.229441E-01	-0.147354E-04	33	0.214868E-01	-0.340515E-05	10	0.100000E 01
	100	11					

NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION
1	0.132028E-02	2	0.131874E-02	3	0.131244E-02	4	0.130827E-02
5	0.122013E-02	6	0.192622E-02	7	0.191969E-02	8	0.183948E-02
9	0.176408E-02	10	0.146919E-02	11	0.344876E-02	12	0.341145E-02
13	0.330069E-02	14	0.287945E-02	15	0.189894E-02	16	0.823834E-02
17	0.910113E-02	18	0.770811E-02	19	0.634184E-02	20	0.357737E-02
21	0.161692E-01	22	0.158383E-01	23	0.144958E-01	24	0.124110E-01
25	0.710942E-02	26	0.196729E-01	27	0.192649E-01	28	0.183827E-01
29	0.145637E-01	30	0.689737E-02	31	0.234247E-01	32	0.229441E-01
33	0.214869E-01	34	0.178425E-01	35	0.111356E-01	36	0.282319E-02
37	0.195475E-02	38	0.181224E-02	39	0.142807E-02	40	0.948808E-03
41	0.262956E-02	42	0.258515E-02	43	0.246783E-02	44	0.218244E-02
45	0.173599E-02	46	0.332587E-02	47	0.304115E-02	48	0.296645E-02
49	0.265110E-02	50	0.229628E-02	51	0.358447E-02	52	0.328465E-02
53	0.341697E-02	54	0.318895E-02	55	0.281622E-02	56	0.289484E-02
57	0.268429E-02	58	0.265448E-02	59	0.254478E-02	60	0.230806E-02
61	0.193829E-02	62	0.198249E-02	63	0.191581E-02	64	0.165364E-02
65	0.170810E-02	66	0.131032E-02	67	0.130842E-02	68	0.136890E-02
69	0.127980E-02	70	0.122163E-02				

NODE	STRESS X	STRESS Y	STRESS XY	MAJOR	MINOR	SHEAR
11	-0.271171E 02	0.789088E 01	0.392137E 00	-0.271115E 02	0.789528E 01	0.175034E 02
16	-0.718134E 02	0.342893E 02	0.132260E-01	-0.718134E 02	0.342893E 02	0.530513E 02
26	-0.180547E 02	0.122406E 03	-0.487375E-02	-0.180547E 02	0.122406E 03	0.702305E 02
31	0.	0.140106E 03	0.	0.	0.140106E 03	0.700532E 02
32	0.	0.181966E 03	0.	0.	0.181966E 03	0.909829E 02
33	0.	0.753746E 02	0.	0.	0.753746E 02	0.376874E 02
34	0.	-0.222445E 02	0.	-0.222445E 02	0.	0.111222E 02
35	0.	0.	0.	0.	0.	0.
36	0.	0.218314E 02	0.	0.	0.218314E 02	0.109157E 02
37	0.	0.130216E 02	0.	0.	0.130216E 02	0.651082E 01
38	0.	0.476573E 01	0.	0.	0.476573E 01	0.238286E 01
39	0.	-0.235768E 01	0.	-0.235768E 01	0.	0.117884E 01
40	0.	0.	0.	0.	0.	0.
41	0.267275E 02	0.107507E 02	-0.116999E-01	0.203587E 02	0.567275E 02	0.798840E 01
51	0.135736E 02	0.780796E 01	-0.296472E-01	0.730901E 01	0.135737E 02	0.288196E 01
56	-0.924389E 00	0.300140E 01	-0.230602E-01	-0.924394E 00	0.300154E 01	0.196297E 01

32	0.228596E-01	-0.755169E-04	33	0.214229E-01	-0.640147E-04	11	0.100000E 01
32	0.227918E-01	-0.116714E-03	33	0.213176E-01	-0.105292E-03	12	0.100000E 01
32	0.226474E-01	-0.144175E-03	33	0.211848E-01	-0.132813E-03	13	0.100000E 01
32	0.224457E-01	-0.162011E-03	33	0.210339E-01	-0.150857E-03	14	0.100000E 01
32	0.222725E-01	-0.173132E-03	33	0.208717E-01	-0.162235E-03	15	0.100000E 01
32	0.220930E-01	-0.179365E-03	33	0.207027E-01	-0.168952E-03	16	0.100000E 01

(Continued)

(Sheet 2 of 5)

Table 6 (Continued)

32	0.217102E-01	-0.182720E+03	33	0.205303E-01	-0.172409E-03	17	0.100000E+01
32	0.217246E-01	-0.183844E+03	33	0.203567E-01	-0.173636E-03	18	0.100000E+01
32	0.215434E-01	-0.182987E+03	33	0.201834E-01	-0.172876E-03	19	0.100000E+01
32	0.213521E-01	-0.181278E+03	33	0.200115E-01	-0.171074E-03	20	0.100000E+01
32	0.211935E-01	-0.178847E+03	33	0.198418E-01	-0.169736E-03	21	0.100000E+01
32	0.210075E-01	-0.175951E+03	33	0.196746E-01	-0.167133E-03	22	0.100000E+01
32	0.208348E-01	-0.172707E+03	33	0.195105E-01	-0.164145E-03	23	0.100000E+01
32	0.206635E-01	-0.169322E+03	33	0.193494E-01	-0.161060E-03	24	0.100000E+01
32	0.204997E-01	-0.165878E+03	33	0.191916E-01	-0.157811E-03	25	0.100000E+01
32	0.203374E-01	-0.162265E+03	33	0.190371E-01	-0.154500E-03	26	0.100000E+01
32	0.201797E-01	-0.158659E+03	33	0.188859E-01	-0.151175E-03	27	0.100000E+01
32	0.200235E-01	-0.155184E+03	33	0.187381E-01	-0.147889E-03	28	0.100000E+01
32	0.198718E-01	-0.151698E+03	33	0.185934E-01	-0.144626E-03	29	0.100000E+01
32	0.197236E-01	-0.148210E+03	33	0.184521E-01	-0.141353E-03	30	0.100000E+01
32	0.195750E-01	-0.144849E+03	33	0.183139E-01	-0.138198E-03	31	0.100000E+01
32	0.194378E-01	-0.141527E+03	33	0.181788E-01	-0.135075E-03	32	0.100000E+01
32	0.192996E-01	-0.138255E+03	33	0.180468E-01	-0.131995E-03	33	0.100000E+01
32	0.191639E-01	-0.135082E+03	33	0.179178E-01	-0.129066E-03	34	0.100000E+01
32	0.190326E-01	-0.131952E+03	33	0.177917E-01	-0.126054E-03	35	0.100000E+01
32	0.189031E-01	-0.128902E+03	33	0.176686E-01	-0.123109E-03	36	0.100000E+01
32	0.187771E-01	-0.125979E+03	33	0.175482E-01	-0.120370E-03	37	0.100000E+01
32	0.186549E-01	-0.123016E+03	33	0.174306E-01	-0.117613E-03	38	0.100000E+01
32	0.185346E-01	-0.120171E+03	33	0.173157E-01	-0.114940E-03	39	0.100000E+01
32	0.184166E-01	-0.117375E+03	33	0.172034E-01	-0.112284E-03	40	0.100000E+01
32	0.183019E-01	-0.114688E+03	33	0.170936E-01	-0.109740E-03	41	0.100000E+01
32	0.181899E-01	-0.112031E+03	33	0.169864E-01	-0.107225E-03	42	0.100000E+01
32	0.180804E-01	-0.109441E+03	33	0.168816E-01	-0.104770E-03	43	0.100000E+01
32	0.179735E-01	-0.106916E+03	33	0.167793E-01	-0.102376E-03	44	0.100000E+01
32	0.178691E-01	-0.104429E+03	33	0.166792E-01	-0.100013E-03	45	0.100000E+01
32	0.177671E-01	-0.102018E+03	33	0.165815E-01	-0.977242E-04	46	0.100000E+01
32	0.176674E-01	-0.996741E+04	33	0.164860E-01	-0.955026E-04	47	0.100000E+01
32	0.175700E-01	-0.973730E+04	33	0.163927E-01	-0.933102E-04	48	0.100000E+01
32	0.174749E-01	-0.951181E+04	33	0.163015E-01	-0.911721E-04	49	0.100000E+01
32	0.173824E-01	-0.929241E+04	33	0.162124E-01	-0.890878E-04	50	0.100000E+01
32	0.172912E-01	-0.907939E+04	33	0.161254E-01	-0.870624E-04	51	0.100000E+01
32	0.172025E-01	-0.886792E+04	33	0.160403E-01	-0.850440E-04	52	0.100000E+01
32	0.171159E-01	-0.866437E+04	33	0.159572E-01	-0.830878E-04	53	0.100000E+01
32	0.170312E-01	-0.846216E+04	33	0.158760E-01	-0.811916E-04	54	0.100000E+01
32	0.169485E-01	-0.827038E+04	33	0.157967E-01	-0.793578E-04	55	0.100000E+01
32	0.168677E-01	-0.808067E+04	33	0.157191E-01	-0.775488E-04	56	0.100000E+01
32	0.167888E-01	-0.789426E+04	33	0.156433E-01	-0.757741E-04	57	0.100000E+01
32	0.167117E-01	-0.771051E+04	33	0.155693E-01	-0.740239E-04	58	0.100000E+01
32	0.166364E-01	-0.753244E+04	33	0.154970E-01	-0.723215E-04	59	0.100000E+01
32	0.165628E-01	-0.735919E+04	33	0.154263E-01	-0.706678E-04	60	0.100000E+01
32	0.164908E-01	-0.719258E+04	33	0.153573E-01	-0.690812E-04	61	0.100000E+01
32	0.164206E-01	-0.702280E+04	33	0.152898E-01	-0.674577E-04	62	0.100000E+01
32	0.163520E-01	-0.686236E+04	33	0.152239E-01	-0.659220E-04	63	0.100000E+01
32	0.162849E-01	-0.670555E+04	33	0.151594E-01	-0.644292E-04	64	0.100000E+01
32	0.162194E-01	-0.655330E+04	33	0.150965E-01	-0.629716E-04	65	0.100000E+01
32	0.161554E-01	-0.639988E+04	33	0.150350E-01	-0.614999E-04	66	0.100000E+01
32	0.160929E-01	-0.624971E+04	33	0.149749E-01	-0.600691E-04	67	0.100000E+01
32	0.160318E-01	-0.610934E+04	33	0.149162E-01	-0.589249E-04	68	0.100000E+01
32	0.159721E-01	-0.596941E+04	33	0.148588E-01	-0.578804E-04	69	0.100000E+01
32	0.159138E-01	-0.583397E+04	33	0.148027E-01	-0.560891E-04	70	0.100000E+01
32	0.158548E-01	-0.569627E+04	33	0.147479E-01	-0.547733E-04	71	0.100000E+01
32	0.158012E-01	-0.556749E+04	33	0.146944E-01	-0.533400E-04	72	0.100000E+01
32	0.157468E-01	-0.543920E+04	33	0.146421E-01	-0.528143E-04	73	0.100000E+01
32	0.156937E-01	-0.530991E+04	33	0.145910E-01	-0.510722E-04	74	0.100000E+01
32	0.156417E-01	-0.519816E+04	33	0.145411E-01	-0.499547E-04	75	0.100000E+01
32	0.155910E-01	-0.507463E+04	33	0.144922E-01	-0.488117E-04	76	0.100000E+01
32	0.155414E-01	-0.495759E+04	33	0.144445E-01	-0.474955E-04	77	0.100000E+01
32	0.154930E-01	-0.483759E+04	33	0.143980E-01	-0.459520E-04	78	0.100000E+01

(Continued) (Sheet 3 of 5)

Table 6 (Continued)

32	0.154457E-01	-0.472888E+04	33	0.143525E-01	-0.455003E+04	80	0.100000E+01
32	0.153965E-01	-0.462288E+04	33	0.143030E-01	-0.444800E+04	81	0.100000E+01
32	0.153544E-01	-0.451866E+04	33	0.142616E-01	-0.434419E+04	82	0.100000E+01
32	0.153102E-01	-0.441296E+04	33	0.142201E-01	-0.424713E+04	83	0.100000E+01
32	0.152671E-01	-0.431566E+04	33	0.141806E-01	-0.415302E+04	84	0.100000E+01
32	0.152250E-01	-0.421131E+04	33	0.141430E-01	-0.405345E+04	85	0.100000E+01
32	0.151838E-01	-0.411588E+04	33	0.141034E-01	-0.396151E+04	86	0.100000E+01
32	0.151436E-01	-0.402871E+04	33	0.140617E-01	-0.387193E+04	87	0.100000E+01
32	0.151044E-01	-0.392562E+04	33	0.140239E-01	-0.377909E+04	88	0.100000E+01
32	0.150660E-01	-0.383488E+04	33	0.139869E-01	-0.369636E+04	89	0.100000E+01
32	0.150285E-01	-0.375028E+04	33	0.139508E-01	-0.361117E+04	90	0.100000E+01
32	0.149918E-01	-0.366955E+04	33	0.139155E-01	-0.352947E+04	91	0.100000E+01
32	0.149560E-01	-0.357860E+04	33	0.138811E-01	-0.344693E+04	92	0.100000E+01
32	0.149218E-01	-0.350082E+04	33	0.138473E-01	-0.339196E+04	93	0.100000E+01
32	0.148868E-01	-0.341442E+04	33	0.138144E-01	-0.329108E+04	94	0.100000E+01
32	0.148534E-01	-0.334065E+04	33	0.137822E-01	-0.321775E+04	95	0.100000E+01
32	0.148208E-01	-0.326083E+04	33	0.137508E-01	-0.314035E+04	96	0.100000E+01
32	0.147889E-01	-0.318981E+04	33	0.137201E-01	-0.307222E+04	97	0.100000E+01
32	0.147578E-01	-0.311378E+04	33	0.136901E-01	-0.299064E+04	98	0.100000E+01
32	0.147273E-01	-0.304986E+04	33	0.136608E-01	-0.298350E+04	99	0.100000E+01
32	0.146976E-01	-0.297827E+04	33	0.136322E-01	-0.284411E+04	100	0.100000E+01
32	0.146685E-01	-0.290658E+04	33	0.136041E-01	-0.280103E+04	101	0.100000E+01
32	0.146402E-01	-0.283967E+04	33	0.135768E-01	-0.278107E+04	102	0.100000E+01
32	0.146124E-01	-0.277538E+04	33	0.135501E-01	-0.267302E+04	103	0.100000E+01
32	0.145853E-01	-0.270734E+04	33	0.135240E-01	-0.260861E+04	104	0.100000E+01
32	0.145589E-01	-0.264562E+04	33	0.134985E-01	-0.254937E+04	105	0.100000E+01
32	0.145330E-01	-0.259163E+04	33	0.134735E-01	-0.249689E+04	106	0.100000E+01
32	0.145076E-01	-0.253145E+04	33	0.134491E-01	-0.248895E+04	107	0.100000E+01
32	0.144830E-01	-0.246855E+04	33	0.134254E-01	-0.237896E+04	108	0.100000E+01
32	0.144588E-01	-0.241499E+04	33	0.134021E-01	-0.232605E+04	109	0.100000E+01
32	0.144352E-01	-0.236017E+04	33	0.133793E-01	-0.227417E+04	110	0.100000E+01
32	0.144122E-01	-0.230498E+04	33	0.133571E-01	-0.222090E+04	111	0.100000E+01
32	0.143896E-01	-0.225404E+04	33	0.133354E-01	-0.217127E+04	112	0.100000E+01
32	0.143676E-01	-0.220316E+04	33	0.133142E-01	-0.212003E+04	113	0.100000E+01
32	0.143461E-01	-0.214773E+04	33	0.132935E-01	-0.206947E+04	114	0.100000E+01
32	0.143252E-01	-0.209903E+04	33	0.132733E-01	-0.202261E+04	115	0.100000E+01
32	0.143046E-01	-0.205243E+04	33	0.132535E-01	-0.197760E+04	116	0.100000E+01
32	0.142846E-01	-0.200582E+04	33	0.132342E-01	-0.192466E+04	117	0.100000E+01
32	0.142650E-01	-0.196209E+04	33	0.132153E-01	-0.189095E+04	118	0.100000E+01
32	0.142458E-01	-0.191268E+04	33	0.131969E-01	-0.184303E+04	119	0.100000E+01
32	0.142271E-01	-0.187377E+04	33	0.131758E-01	-0.180540E+04	120	0.100000E+01
32	0.142088E-01	-0.182779E+04	33	0.131612E-01	-0.176154E+04	121	0.100000E+01
32	0.141910E-01	-0.178352E+04	33	0.131440E-01	-0.171807E+04	122	0.100000E+01
32	0.141735E-01	-0.174720E+04	33	0.131272E-01	-0.168374E+04	123	0.100000E+01
32	0.141565E-01	-0.170198E+04	33	0.131108E-01	-0.164045E+04	124	0.100000E+01
32	0.141378E-01	-0.166216E+04	33	0.130947E-01	-0.160459E+04	125	0.100000E+01
32	0.141236E-01	-0.162971E+04	33	0.130790E-01	-0.156685E+04	126	0.100000E+01
32	0.141076E-01	-0.159821E+04	33	0.130637E-01	-0.158572E+04	127	0.100000E+01
32	0.140921E-01	-0.155604E+04	33	0.130487E-01	-0.149930E+04	128	0.100000E+01
32	0.140759E-01	-0.152041E+04	33	0.130340E-01	-0.144560E+04	129	0.100000E+01
32	0.140626E-01	-0.148849E+04	33	0.130197E-01	-0.140009E+04	130	0.100000E+01
32	0.140475E-01	-0.144870E+04	33	0.130058E-01	-0.139574E+04	131	0.100000E+01
32	0.140334E-01	-0.141874E+04	33	0.129921E-01	-0.136242E+04	132	0.100000E+01
32	0.140195E-01	-0.138682E+04	33	0.129788E-01	-0.138596E+04	133	0.100000E+01
32	0.140030E-01	-0.135401E+04	33	0.129658E-01	-0.130236E+04	134	0.100000E+01
32	0.139728E-01	-0.132174E+04	33	0.129530E-01	-0.128373E+04	135	0.100000E+01
	1C* 13*						

(Continued) (Sheet 4 of 5)

Table 6 (Concluded)

NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION
1	0.144239E-02	2	0.144020E-02	3	0.143247E-02	4	0.14[illegible]0E-02
5	0.132320E-02	6	0.218278E-02	7	0.217239E-02	8	0.2[illegible]2E-02
9	0.202409E-02	10	0.174293E-02	11	0.357043E-02	12	0.35[illegible]8E-02
13	0.344913E-02	14	0.310689E-02	15	0.233245E-02	16	0.[illegible]9E-02
17	0.575330E-02	18	0.649756E-02	19	0.545816E-02	20	0.35[illegible]5E-02
21	0.112099E-01	22	0.104595E-01	23	0.102987E-01	24	0.8[illegible]9E-02
25	0.500078E-02	26	0.128057E-01	27	0.125068E-01	28	0.1[illegible]9E-01
29	0.921709E-02	30	0.578785E-02	31	0.143857E-01	32	0.139[illegible]E-01
33	0.127535E-01	34	0.100928E-01	35	0.647877E-02	36	0.1[illegible]E-01
37	0.111140E-01	38	0.100497E-01	39	0.964059E-02	40	0.[illegible]9E-02
41	0.996468E-02	42	0.968978E-02	43	0.956891E-02	44	0.[illegible]0E-02
45	0.533997E-02	46	0.846325E-02	47	0.834463E-02	48	0.[illegible]E-02
49	0.685968E-02	50	0.466961E-02	51	0.589004E-02	52	0.[illegible]2E-02
53	0.486530E-02	54	0.438169E-02	55	0.313005E-02	56	0.[illegible]1E-02
57	0.272724E-02	58	0.278529E-02	59	0.263721E-02	60	0.[illegible]E-02
61	0.186291E-02	62	0.185686E-02	63	0.183860E-02	64	0.17[illegible]3E-02
65	0.159910E-02	66	0.138873E-02	67	0.182731E-02	68	0.[illegible]E-02
69	0.130280E-02	70	0.126077E-02				

NODE	STRESS X	STRESS Y	STRESS XY	MAJOR	MINOR	SHEAR
11	-0.167903E 02	0.726670E 01	0.296240E 00	-0.160020E 02	0.716987E [illegible]	0.[illegible]9E 02
16	-0.329246E 02	0.294755E 02	-0.823056E-01	-0.329248E 02	0.294756E [illegible]	0.[illegible]2E 02
26	0.358930E 02	0.954762E 02	0.681974E-01	0.358940E 02	0.994263E 02	0.[illegible]2E 02
31	0.	0.976345E 02	0.	0.	0.976345E 02	0.[illegible]3E 02
32	0.	0.134809E 03	0.	0.	0.134809E 03	0.[illegible]E 02
33	0.	0.370690E 02	0.	0.	0.370690E 02	0.[illegible]E 02
34	0.	-0.228712E 02	0.	-0.228712E 02	0.	0.[illegible]E 02
35	0.	1.	0.	0.	0.	0.
36	0.	0.648998E 02	0.	0.	0.648998E 02	0.[illegible]E 02
37	0.	0.607103E 02	0.	0.	0.607103E 02	0.[illegible]2E 02
38	0.	0.455850E 02	0.	0.	0.455850E 02	0.227675E 02
39	0.	-0.193694E 01	0.	-0.193694E 01	0.	0.[illegible]E 00
40	0.	0.	0.	0.	0.	0.
41	-0.172660E 02	0.482348E 02	0.608399E-01	-0.172660E 02	0.482349E 02	0.327507E 02
51	-0.259216E 02	0.129343E 02	-0.103583E 00	-0.259329E 02	0.129870E 02	0.[illegible]E 02
56	-0.115910E 02	0.392042E 01	-0.117667E 00	-0.115918E 02	0.392132E 01	0.[illegible]5E 01

(Sheet 5 of 5)

Table 7. Example Problem 3, Input Data for a Two-Slab Pavement on Three-Layer Elastic Solid, 100 Percent Shear Transfer

GENERAL PURPOSE DATA FORM

PROGRAM			DATE	
REQUESTED BY	PREPARED BY	CHECKED BY	PAGE	OF

```
    1
  2-slab pavement, 3-layer elastic solid subgrade, 100 percent shear transfer across the joint.  SYM. Loading.
    2 0.15   8.  6000000.    10000.  0.4    3    0    0    0   21    1
    7    7    5    1   16    3
   18   23   28   31   32   33   34   35   36   37   38   39   40   43   48   53
    60000.       0.4   30000.        0.4    10000.       0.4
       40.       60.
        0.       50.       90.      130.      160.      170.      180.      180.
      190.      200.      230.      270.      310.      360.
        0.       10.       20.       40.       70.
    0    0    8  300  300    2    0    0
```

```
        0.      100.      0.01     0.001       0.1        1.
   31   32
    80000.00
   17   18   21   22   25   26   29   30
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
       -1.        1.       -1.        1.
```

WES FORM 1233

Table 8

Printout of the Computer Output for Example Problem 3, Three-Layer Elastic Subgrade, 100 Percent Shear Transfer Across the Joint

```
                 FINITE ELEMENT ANALYSIS OF CONCRETE PAVEMENTS

          NO. OF SLABS =         2  POISSON RATIO OF CONCRETE=    0.1500     THICKNESS OF CONCRETE=   12.0000
      MODULUS OF CONCRETE= 0.600E 07          MODULUS OF SUBGRADE= 0.400E 04  POISSON RATIO OF SUBGRADE=   0.4000

  NSYM=          3    NSTGH=        1   NSTCHF=        0      NPUNCH=        0        LTR=        0
  NX1=           7    NX2=          7       NY=        5       NCYLE=        1     NCTCUN=        0    NB=       21
  NLA=           3

  STRESSES AT THE FOLLOWING NODES ARE TO BE PRINTED=
    11          16         26         31         32         33          34         35         36         37
    38          39         40         41         51         56

  MODULUS AND POISSON'S RATIO VALUES AT THE SUBGRADE ARE
        0.60000E 05      0.40  0.30000E 05      0.40  0.10000E 05       0.40

  THE THICKNESSES OF EACH LAYER ARE     40.000         60.000
 VALUES OF X ARE=
   0.        50.000      90.000     130.000     160.000     170.000     180.000     188.000     190.000     200.000
 230.000    270.000     310.000     360.000

 VALUES OF Y ARE=
   0.        10.000      20.000      40.000      70.000
0.69125164E-04  0.19554276E-04  0.96323635E-05  0.63931593E-05  0.49366059E-05  0.33675622E-05  0.26630496E-05
0.21219631E-05  0.16061605E-05  0.15072059E-05  0.13149808E-05  0.10287961E-05  0.96347322E-06  0.67941824E-06
0.55724021E-06  0.49563823E-06  0.45450823E-06  0.42035961E-06  0.39293093E-06  0.35937362E-06  0.33183811E-06
0.17826016E-04  0.31775176E-05  0.17321481E-05  0.13641368E-05  0.10788182E-05  0.86966818E-06  0.74974887E-06
0.64155717E-06  0.57292069E-06  0.50720585E-06  0.46332316E-06  0.38740812E-06  0.33672028E-06  0.26413216E-06
0.21682169E-06  0.18145493E-06  0.15317931E-06  0.12909944E-06  0.11098846E-06  0.90122296E-07  0.75603298E-07
     EXP UNDERFLO  AT LOCATION       055612
     EXP UNDERFLO  AT LOCATION       055612
     EXP UNDERFLO  AT LOCATION       055613


  NMAP=     3       NTEMP=     0       NLOAD=     8        ICL=    49         NCK=     2         NNT=     0
  TEMP=   0.           U= 100.00000      RFJ=   0.50000     DEL=   0.01000     DELF=   0.00100    ICLF=   400
  EFF=1.000         NGAPE=    0       IGNOR=

  THE FOLLOWING NODES ARE USED TO CHECK CONVERGENCE=
     31        32

  AMOUNT OF INITIAL SUBGRADE AND GAP AT THE NODES IS=
   1   0.         2   0.         3   0.         4   0.         5   0.         6   0.         7   0.
   8   0.         9   0.        10   0.        11   0.        12   0.        13   0.        14   0.
  15   0.        16   0.        17   0.        18   0.        19   0.        20   0.        21   0.
  22   0.        23   0.        24   0.        25   0.        26   0.        27   0.        28   0.
  29   0.        30   0.        31   0.        32   0.        33   0.        34   0.        35   0.
  36   0.        37   0.        38   0.        39   0.        40   0.        41   0.        42   0.
  43   0.        44   0.        45   0.        46   0.        47   0.        48   0.        49   0.
  50   0.        51   0.        52   0.        53   0.        54   0.        55   0.        56   0.
  57   0.        58   0.        59   0.        60   0.        61   0.        62   0.        63   0.
  64   0.        65   0.        66   0.        67   0.        68   0.        69   0.        70   0.

  WHEEL LOADS ARE APPLIED ON THE FOLLOWING ELEMENTS AND COORDINATES=
            17       -1.00000       1.00000       -1.00000       1.00000
            18       -1.00000       1.00000       -1.00000       1.00000
            21       -1.00000       1.00000       -1.00000       1.00000
            22       -1.00000       1.00000       -1.00000       1.00000
            25       -1.00000       1.00000       -1.00000       1.00000
            26       -1.00000       1.00000       -1.00000       1.00000


            29       -1.00000       1.00000       -1.00000       1.00000
            30       -1.00000       1.00000       -1.00000       1.00000
  TOTAL UNIFORMLY APPLIED LOAD INPUT=    80000.00  TOTAL LOAD CALCULATED=     80000.00

    NIC=         1


THE DIFFERENCES BETWEEN TWO ITERATIONS ARE
TABULATED BELOW,THE LAST INTEGER + REAL NUMBERS BEING THE ITERA  TION NUMBER AND THE RELAXATION FACTOR,RESPECTIVELY

   NODE    DEFLECTION AND DEFLECTION DIFFERENCE
    31      0.248473E-01      0.676657E-02     32      0.231461E-01      0.645525E-02     1      0.500000E 00
    31      0.340773E-01      0.109513E-01     32      0.332903E-01      0.101542E-01     2      0.500000E 00
    31      0.386131E-01      0.451781E-02     32      0.377998E-01      0.454950E-02     3      0.500000E 00
    31      0.431171E-01      0.450406E-02     32      0.423031E-01      0.450332E-02     4      0.500000E 00
    31      0.472471E-01      0.412299E-02     32      0.464201E-01      0.411698E-02     5      0.500000E 00
    31      0.509478E-01      0.372273E-02     32      0.501153E-01      0.369526E-02     6      0.500000E 00
    31      0.542484E-01      0.330053E-02     32      0.534086E-01      0.329323E-02     7      0.500000E 00
    31      0.571773E-01      0.293390E-02     32      0.563358E-01      0.292720E-02     8      0.500000E 00
    31      0.597825E-01      0.260527E-02     32      0.589350E-01      0.259924E-02     9      0.500000E 00
```

E = 6,000,000 psi   ν = 0.15

40" E_1 = 60000 psi   ν = 0.4

60" E_2 = 30000 psi   ν = 0.4

E_3 = 10000 psi   ν = 0.4

Layer information

DEF1(I)

DEF2(I)

I=1,21

can be ignored

(Continued)

(Sheet 1 of 3)

Table 8 (Continued)

31	0.6239[illegible]2E-01	0.231268E-02	32	0.612423E-01	0.230733E-02	10	0.500000E 00
31	0.6414[illegible]6E-01	0.205240E-02	32	0.632933E-01	0.204763E-02	11	0.500000E 00
31	0.6595[illegible]3E-01	0.182169E-02	32	0.651074E-01	0.181745E-02	12	0.500000E 00
31	0.6750[illegible]7E-01	0.161038E-02	32	0.667200E-01	0.161262E-02	13	0.500000E 00
31	0.6902[illegible]7E-01	0.143455E-02	32	0.681913E-01	0.143121E-02	14	0.500000E 00
31	0.702975E-01	0.127331E-02	32	0.694216E-01	0.127036E-02	15	0.500000E 00
31	0.714233E-01	0.112775E-02	32	0.705487E-01	0.112712E-02	16	0.500000E 00
31	0.7242[illegible]E-01	0.100259E-02	32	0.715490E-01	0.100027E-02	17	0.500000E 00
31	0.7331[illegible]5E-01	0.889762E-03	32	0.724367E-01	0.887693E-03	18	0.500000E 00
31	0.7410[illegible]E-01	0.789775E-03	32	0.732244E-01	0.787732E-03	19	0.500000E 00
31	0.7480[illegible]7E-01	0.701200E-03	32	0.739233E-01	0.698879E-03	20	0.500000E 00
31	0.754270E-01	0.622755E-03	32	0.745441E-01	0.623803E-03	21	0.500000E 00
31	0.759797E-01	0.551741E-03	32	0.750946E-01	0.550456E-03	22	0.500000E 00
31	0.764074E-01	0.48[illegible]66E-03	32	0.755831E-01	0.488539E-03	23	0.500000E 00
31	0.769341E-01	0.434742E-03	32	0.760168E-01	0.433725E-03	24	0.500000E 00
31	0.7743[illegible]3E-01	0.385696E-03	32	0.764016E-01	0.364798E-03	25	0.500000E 00
31	0.775372E-01	0.342349E-03	32	0.767432E-01	0.341551E-03	26	0.500000E 00
31	0.779[illegible]9E-01	0.303767E-03	32	0.770462E-01	0.303064E-03	27	0.500000E 00
31	0.7820[illegible]5E-01	0.269954E-03	32	0.773152E-01	0.268922E-03	28	0.500000E 00
31	0.7844[illegible]8E-01	0.239342E-03	32	0.775539E-01	0.238789E-03	29	0.500000E 00
31	0.78[illegible]71E-01	0.212254E-03	32	0.777657E-01	0.211757E-03	30	0.500000E 00
31	0.7884[illegible]5E-01	0.188424E-03	32	0.779537E-01	0.187986E-03	31	0.500000E 00
31	0.7901[illegible]6E-01	0.167052E-03	32	0.781204E-01	0.166670E-03	32	0.500000E 00
31	0.791[illegible]E-01	0.148312E-03	32	0.782683E-01	0.147966E-03	33	0.500000E 00
31	0.792975E-01	0.131629E-03	32	0.783996E-01	0.131315E-03	34	0.500000E 00
31	0.794076E-01	0.117045E-03	32	0.785164E-01	0.116777E-03	35	0.500000E 00
31	0.7955[illegible]E-01	0.103582E-03	32	0.786198E-01	0.103342E-03	36	0.500000E 00
31	0.7960[illegible]1E-01	0.920303E-04	32	0.787115E-01	0.917912E-04	37	0.500000E 00
31	0.796468E-01	0.816537E-04	32	0.787930E-01	0.814628E-04	38	0.500000E 00
31	0.7979[illegible]4E-01	0.725933E-04	32	0.788654E-01	0.724290E-04	39	0.500000E 00

IC= 37

NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION
1	0.239635E-01	2	0.239317E-01	3	0.236348E-01	4	0.234614E-01
5	0.[illegible]623E-01	6	0.319491E-01	7	0.318787E-01	8	0.316703E-01
9	0.[illegible]E-01	10	0.290357E-01	11	0.411418E-01	12	0.410020E-01
13	0.405884E-01	14	0.390332E-01	15	0.355005E-01	16	0.552109E-01
17	0.54[illegible]425E-01	18	0.539312E-01	19	0.505745E-01	20	0.437012E-01
21	0.[illegible]96692E-01	22	0.670109E-01	23	0.671648E-01	24	0.612904E-01
25	0.[illegible]90[illegible]E-01	26	0.747451E-01	27	0.737631E-01	28	0.717752E-01
29	0.[illegible]49914E-01	30	0.535021E-01	31	0.797594E-01	32	0.788654E-01
33	0.765512E-01	34	0.656758E-01	35	0.561731E-01	36	0.795933E-01
37	0.[illegible]36997E-01	38	0.761866E-01	39	0.655154E-01	40	0.560221E-01
41	0.[illegible]461[illegible]E-01	42	0.738389E-01	43	0.716592E-01	44	0.648739E-01
45	0.[illegible]340[illegible]E-01	46	0.695765E-01	47	0.687185E-01	48	0.678736E-01
49	0.[illegible]120[illegible]E-01	50	0.532291E-01	51	0.551811E-01	52	0.548530E-01
53	0.[illegible]390[illegible]E-01	54	0.505492E-01	55	0.436850E-01	56	0.411399E-01
57	0.[illegible]10031E-01	58	0.405867E-01	59	0.390320E-01	60	0.355014E-01
61	0.319519E-01	62	0.318814E-01	63	0.316729E-01	64	0.308792E-01
65	0.290376E-01	66	0.239665E-01	67	0.239346E-01	68	0.238874E-01
69	0.234631E-01	70	0.225628E-01				

NODE	STRESS X	STRESS Y	STRESS XY	MAJOR	MINOR	SHEAR
11	-0.961144E 02	0.867842E 02	0.127523E 01	-0.961233E 02	0.867931E 02	0.914582E 02
16	-0.137163E 03	0.219924E 03	-0.877998E 00	-0.137165E 03	0.219926E 03	0.178546E 03
26	0.153704E 03	0.603071E 03	0.486213E 00	0.153705E 03	0.603022E 03	0.224658E 03
31	0.	0.658640E 03	0.	0.	0.658640E 03	0.329320E 03
32	0.	0.616682E 03	0.	0.	0.616682E 03	0.308341E 03
33	0.	0.380764E 03	0.	0.	0.380764E 03	0.190382E 03
34	0.	-0.138777E 02	0.	-0.138777E 02	0.	0.693883E 01
35	0.	0.	0.	0.	0.	0.
36	0.	0.658361E 03	0.	0.	0.658361E 03	0.329180E 03
37	0.	0.616408E 03	0.	0.	0.616408E 03	0.308204E 03
38	0.	0.380429E 03	0.	0.	0.380459E 03	0.190229E 03
39	0.	-0.138763E 02	0.	-0.138763E 02	0.	0.693815E 01
40	0.	0.	0.	0.	0.	0.
41	0.1[illegible]173E 03	0.603121E 03	-0.484627E 00	0.158177E 03	0.603121E 03	0.223465E 03
51	-0.135664E 03	0.219948E 03	0.872837E 00	-0.135666E 03	0.219950E 03	0.177808E 03
56	-0.957392E 02	0.868007E 02	-0.127502E 01	-0.957181E 02	0.868096E 02	0.912639E 02

31	0.798230E-01	0.641081E-04	32	0.789295E-01	0.640191E-04	40	0.500000E 00

IC= 40

NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION
1	0.239941E-01	2	0.239623E-01	3	0.238653E-01	4	0.234914E-01
5	0.[illegible]E-01	6	0.319878E-01	7	0.319174E-01	8	0.317088E-01
9	0.309140E-01	10	0.290719E-01	11	0.411884E-01	12	0.410485E-01
13	0.406347E-01	14	0.390784E-01	15	0.359436E-01	16	0.552664E-01
17	0.[illegible]49377E-01	18	0.539883E-01	19	0.506283E-01	20	0.437523E-01
21	0.[illegible]7300E-01	22	0.690723E-01	23	0.672258E-01	24	0.613499E-01
25	0.[illegible]95735E-01	26	0.748032E-01	27	0.743259E-01	28	0.718378E-01
29	0.536559E-01	30	0.539659E-01	31	0.793236E-01	32	0.789295E-01
33	0.764[illegible]E-01	34	0.637377E-01	35	0.562319E-01	36	0.796763E-01
37	0.[illegible]78260E-01	38	0.762639E-01	39	0.685956E-01	40	0.560976E-01
41	0.716962E-01	42	0.739111E-01	43	0.717268E-01	44	0.649485E-01
45	0.[illegible]3471[illegible]E-01	46	0.696486E-01	47	0.689904E-01	48	0.671450E-01
49	0.[illegible]12734E-01	50	0.508937E-01	51	0.552400E-01	52	0.549117E-01
53	0.53[illegible]E-01	54	0.536039E-01	55	0.437379E-01	56	0.411860E-01
57	0.[illegible]1046E-01	58	0.406331E-01	59	0.391773E-01	60	0.355443E-01
61	0.319924E-01	62	0.319197E-01	63	0.317110E-01	64	0.309166E-01
65	0.290739E-01	66	0.239988E-01	67	0.239648E-01	68	0.238675E-01
69	0.[illegible]3492[illegible]E-01	70	0.229919E-01				

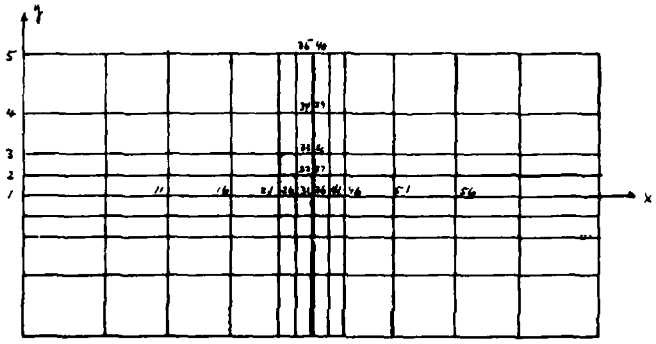
100% shear transfer

(Continued)

(Sheet 2 of 3)

Table 8 (Concluded)

NODE	STRESS X	STRESS Y	STRESS XY	MAJOR	MINOR	SHEAR
11	-0.961410E 02	0.868457E 02	0.127916E 01	-0.961499E 02	0.868946E 02	0.915022E 02
16	-0.137128E 03	0.220012E 03	-0.877890E 00	-0.137130E 03	0.220015E 03	0.178572E 03
26	0.153867E 03	0.603169E 03	0.496615E 00	0.153866E 03	0.603160E 03	0.224647E 03
31	0.	0.658743E 03	0.	0.	0.658743E 03	0.329372E 03
32	0.	0.616798E 03	0.	0.	0.616798E 03	0.308399E 03
33	0.	0.380849E 03	0.	0.	0.380849E 03	0.190425E 03
34	0.	-0.138091E 02	0.	-0.138091E 02	0.	0.690453E 01
35	0.	0.	0.	0.	0.	0.
36	0.	0.658499E 03	0.	0.	0.658499E 03	0.329250E 03
37	0.	0.616541E 03	0.	0.	0.616541E 03	0.308270E 03
38	0.	0.380585E 03	0.	0.	0.380585E 03	0.190293E 03
39	0.	-0.137966E 02	0.	-0.137966E 02	0.	0.689828E 01
40	0.	0.	0.	0.	0.	0.
41	0.156066E 03	0.603239E 03	-0.494736E 00	0.156065E 03	0.603239E 03	0.223587E 03
51	-0.135799E 03	0.220035E 03	0.873293E 00	-0.135801E 03	0.220037E 03	0.177919E 03
56	-0.957822E 02	0.868610E 02	-0.127495E 01	-0.957911E 02	0.868699E 02	0.913305E 02



(Sheet 3 of 3)

resting on a three-layer linear elastic subgrade. One hundred percent joint efficiency is assumed. The finite element grid pattern is the same as shown in Figure 2.

49. Table 8 shows the printout of the computer output for Example problem 3. The layered subgrade information indicates that the elastic moduli of the three-layer subgrade are 60,000, 30,000, and 10,000 psi and that the Poisson's ratio in each layer is 0.4. Because of the assumption of 100 percent shear transfer across the joint and the symmetrical loading, the stresses and deflections at corresponding nodes across the joint are nearly identical.

Example Problem 4: A Four-Slab Pavement System on Elastic Solids, Symmetrically Loaded, with 100 Percent Shear Transfer Across the Joint

50. Figure 3 shows the finite element layout for a four-slab pavement system with the load applied symmetrically at the pavement's center. This is the only option for the analysis of a four-slab pavement system by use of the WESLAYER program. Although it is a four-slab system, the program analyzes only one-quarter of the system, i.e., one slab. Consequently, 100 percent joint efficiency should be assumed

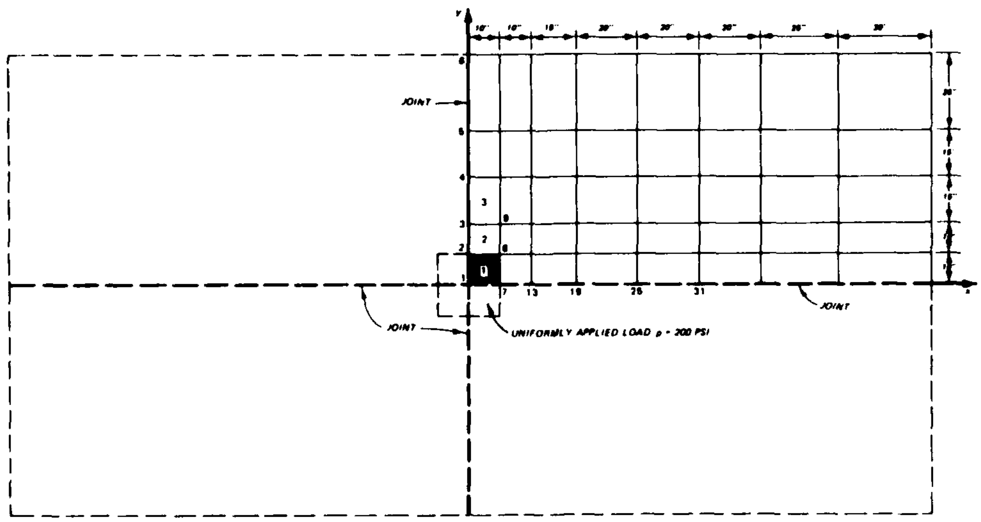


Figure 3. Finite element layout for Example problem 4, symmetrically loaded four-slab system

for the problem. The coordinates and loading condition input into the program are shown in Figure 3.

51. The input data for this problem are given in Table 9. It should be pointed out that the parameter NSYM is input as 5 for a four-slab system. The number of slab NSLAB is input as 1, instead of 4, because there is only one slab involved in the computation. (In the case for a single slab symmetrically loaded, NSYM should be input as 4.)

52. The printout of the computer output for Example problem 4 is presented in Table 10. The printout is self-explanatory. Because of symmetry, the computed stresses and deflections at nodal points 2, 3, 4, and 5 should be very close to those computed at nodes 7, 13, 19, and 25, respectively. The computed results show that it is true only at nodal points 2 and 7. At nodes closer to the free edge of the pavement, the discrepancy becomes greater. This is believed to be caused by the fact that the slabs have different dimensions in the X- and Y-directions. It is also to be noted that at nodes 1 and 6, i.e., nodes at the corners of the slabs, the stresses vanish.

Table 9. Example Problem 4, Input Data for a Four-Slab Pavement on an Elastic Solid, Symmetrically Loaded on Both X- and Y-Axes, 100 Percent Shear Transfer Across the Joints

GENERAL PURPOSE DATA FORM

PROGRAM | DATE

REQUESTED BY | PREPARED BY | CHECKED BY | PAGE OF

```
    1
  Four-slab pavement on elastic solids, symmetrically loaded on both X- and Y-axes.
    1 0.15   8.  4000000.    10000.  0.4    3    0    0    0   21    0
    9    0    6    1   13    1
    1    2    3    4    5    6    7    8    9   13   19   25   31
   0.  10.  20.  35.  55.  75.  95. 120. 150.
   0.  10.  20.  35.  50.  75.
   0.    0    1  300  300    2    0    0
        0.      200.     0.001    0.0001       0.5        1.
    1    8
    20000.00
```

```
    1
       -1.        1.       -1.        1.
```

WES FORM 1233 EDITION OF SEP 62 WILL BE USED UNTIL EXHAUSTED

Table 10. Printout of Computer Output for Example Problem 4, a Four-Slab Pavement System on Elastic Solids, 100 Percent Shear Transfer Across the Joint

```
4-SLAB PAVT,EFF12=1.  1 LAYER SUBGRADE

             FINITE ELEMENT ANALYSIS OF CONCRETE SLABS
           NO. OF SLABS =          1  POISSON RATIO OF CONCRETE=     0.1500      THICKNESS OF CONCRETE=     8.0000
    MODULUS OF CONCRETE= 5.400E 06          MODULUS OF SUBGRADE= 0.100E 05  POISSON RATIO OF SUBGRADE=    0.4000

  NSYM=          5     NRUN=          1   NSTORE=          0   NPUNCH=     0    LYRS      0     NLAS    1
   NX1=          9      NX2=          0       NY=          6   NCYLE=         1      NSTOR=        0      NE=        24
  STRESSES AT THE FOLLOWING NODES ARE TO BE PRINTED:
    1          2          3          4          5          6          7          8          9         53
   19         25         31

VALUES OF X ARE
    0.        10.000     20.000     35.000     55.000     75.000     95.000    120.000    150.000
  VALUES OF Y ARE:
    0.        10.000     20.000     35.000     55.000     75.000

   NGAP=    0       NTEMP=      0       NLOAD=     1          ICL=   300          NCK=     2          NBYO     0
   TEMP=   0.          G= 200.00000      REJ=   0.50000       DEL=   0.00500      DELF=  0.00010      IOUT=  300
   EFF =  1.00      IGNORE      1

   THE FOLLOWING NODES ARE USED TO CHECK CONVERGENCE:
      1        8

   AMOUNT OF INITIAL CURLING AND GAP AT THE NODES IS:
  1   0.          2   0.          3   0.          4   0.          5   0.          6   0.          7   0.
  8   0.          9   0.         10   0.         11   0.         12   0.         13   0.         14   0.
 15   0.         16   0.         17   0.         18   0.         19   0.         20   0.         21   0.
 22   0.         23   0.         24   0.         25   0.         26   0.         27   0.         28   0.
 29   0.         30   0.         31   0.         32   0.         33   0.         34   0.         35   0.
 36   0.         37   0.         38   0.         39   0.         40   0.         41   0.         42   0.
 43   0.         44   0.         45   0.         46   0.         47   0.         48   0.         49   0.
 50   0.         51   0.         52   0.         53   0.         54   0.

  WHEEL LOADS ARE APPLIED ON THE FOLLOWING ELEMENTS AND COORDINATES:
          1        -1.00000          1.00000        -1.00000          1.00000

   NIC=         1

THE DIFFERENCES BETWEEN TWO ITERATIONS ARE
TABULATED BELOW,THE LAST INTEGER + REAL NUMBERS BEING THE ITERA  TION NUMBER AND THE RELAXATION FACTOR,RESPECTIVELY

     NODE    DEFLECTION AND DEFLECTION DIFFERENCE
   1       0.113007E 00      0.186027E-01      8       0.841607E-01       0.166021E-01     1       0.500000E 00
   1       0.121960E 00      0.896475E-02      8       0.924075E-01       0.832801E-02     2       0.500000E 00
   1       0.127351E 00      0.538298E-02      8       0.975648E-01       0.507730E-02     3       0.500000E 00
   1       0.130839E 00      0.345850E-02      8       0.100837E 00       0.329206E-02     4       0.500000E 00
   1       0.133006E 00      0.229220E-02      8       0.102969E 00       0.210210E-02     5       0.500000E 00
   1       0.134532E 00      0.147068E-02      8       0.104561E 00       0.139291E-02     6       0.500000E 00
   1       0.135493E 00      0.960965E-03      8       0.105271E 00       0.909900E-03     7       0.500000E 00
```

(Continued)

(Sheet 1 of 3)

Table 10 (Continued)

1	0.136121E 03	0.627963E-03	8	0.105866E 00	0.594600E-03	8	0.500000E 00
1	0.136532E 00	0.410371E-03	8	0.106255E 00	0.388575E-03	9	0.500000E 00
1	[illegible]	[illegible]	8	0.106508E 00	[illegible]	10	0.500000E 00
1	0.136979E 03	0.175254E-03	8	0.106674E 00	0.165945E-03	11	0.500000E 00
1	0.137089E 03	0.114525E-03	8	0.106783E 00	0.100437E-03	12	0.500000E 00
1	0.137164E 00	0.748485E-04	8	0.106854E 00	0.700709E-04	13	0.500000E 00
1	0.137213E 03	0.489075E-04	8	0.106900E 00	0.468100E-04	14	0.500000E 00
1	0.137249E 00	0.319555E-04	8	0.106930E 00	0.308605E-04	15	0.500000E 00
1	0.137266E 00	0.208894E-04	8	0.106950E 00	0.197794E-04	16	0.500000E 00
1	0.137279E 03	0.136844E-04	8	0.106963E 00	0.129323E-04	17	0.500000E 00
1	0.137288E 03	0.891462E-05	8	0.106971E 00	0.844480E-05	18	0.500000E 00
	$C0 18						

NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION
1	0.137280E 00	2	0.121484E 00	3	0.105861E 00	4	0.829719E-01
5	0.645720E-01	6	0.401894E-01	7	0.121028E 00	8	0.808971E 00
9	0.989978E-01	10	0.737461E-01	11	0.575832E-01	12	[illegible]
13	0.104401E 00	14	0.926089E-01	15	0.809942E-01	16	0.647313E-01
17	0.506759E-01	18	0.306401E-01	19	0.817137E-01	20	0.738538E-01
21	0.644464E-01	22	0.523082E-01	23	0.413635E-01	24	0.259384E-01
25	0.581687E-01	26	0.529779E-01	27	0.469871E-01	28	0.389408E-01
29	0.314389E-01	30	0.197147E-01	31	0.418845E-01	32	0.382491E-01
33	0.346364E-01	34	0.298730E-01	35	0.243554E-01	36	[illegible]
37	0.320087E-01	38	0.286645E-01	39	0.263042E-01	40	0.228437E-01
41	0.195084E-01	42	0.140734E-01	43	0.224761E-01	44	0.210316E-01
45	0.195843E-01	46	0.174676E-01	47	0.154411E-01	48	0.125815E-01
49	0.199190E-01	50	0.149781E-01	51	0.141000E-01	52	0.129300E-01
53	0.118662E-01	54	0.101194E-01				

NODE	STRESS X	STRESS Y	STRESS XY	MAJOR	MINOR	SHEAR
1	0.	0.	0.	0.	0.	0.
2	0.	0.156846E 03	0.	0.	0.354886E 03	0.784282E 02
3	0.	-0.206073E 03	0.	-0.206073E 03	0.	0.103037E 03
4	0.	-0.290063E 03	0.	-0.290063E 03	0.	[illegible]
5	0.	-0.262228E 03	0.	-0.262228E 03	0.	0.131114E 03
6	0.	0.	0.	0.	0.	0.
7	0.152940E 03	0.	0.	0.	0.152940E 03	0.764700E 02
8	0.162795E 02	0.233082E 02	0.302838E 03	-0.282467E 03	0.322051E 03	0.302259E 03
9	-0.920499E 02	-0.163523E 03	0.311970E 03	-0.424694E 03	0.209139E 03	0.316910E 03
13	-0.217012E 03	0.	0.	-0.217012E 03	0.	[illegible]
19	-0.336277E 03	0.	0.	-0.336277E 03	0.	0.168138E 03
25	-0.299484E 03	0.	0.	-0.299484E 03	0.	0.149742E 03
31	-0.217885E 03	0.	0.	-0.217885E 03	0.	[illegible]

1	0.137294E 00	0.582022E-05	8	0.106977E 00	0.551902E-05	18	0.500000E 00
	TE0 19						

NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION	NODE	DEFLECTION
1	0.137294E 00	2	0.121442E 00	3	0.105867E 00	4	0.829972E-01
5	0.645769E-01	6	0.401898E-01	7	0.121026E 00	8	0.808977E 00
9	0.980082E-01	10	0.737742E-01	11	0.575880E-01	12	0.351869E-01
13	0.104407E 00	14	0.926183E-01	15	0.809994E-01	16	0.647363E-01
17	0.506890E-01	18	0.306443E-01	19	0.817190E-01	20	0.738590E-01
21	0.644714E-01	22	0.525110E-01	23	0.413680E-01	24	0.250425E-01
25	0.581714E-01	26	0.529820E-01	27	0.469910E-01	28	0.389453E-01
29	0.314429E-01	30	0.197186E-01	31	0.418891E-01	32	0.382936E-01
33	0.346487E-01	34	0.293772E-01	35	0.243594E-01	36	0.182871E-01
37	0.320044E-01	38	0.286686E-01	39	0.263082E-01	40	0.228476E-01
41	0.195121E-01	42	0.140788E-01	43	0.224798E-01	44	0.210352E-01
45	0.195839E-01	46	0.174710E-01	47	0.154444E-01	48	0.121545E-01

(Continued)

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Table 10 (Concluded)

57	0.1991E-01 [illegible]	58	0.1407928E-01 [illegible]	61	0.1410308E-05 [illegible]	72	0.5298898E-01 [illegible]
53	0.1284998E-01 [illegible]	54	0.1811008E-01 [illegible]				

NODE	STRESS X	STRESS Y	STRESS XY	MAJOR	MINOR	SHEAR
1	0.	0.	0.	0.	0.	0.
2	0.	-0.1960497E 03	0.	0.	0.1960497E 03	0.7842046E 02 [illegible]
3	0.	-0.2860716E 03	0.	-0.2860716E 03	0.	0.[illegible] 03
4	0.	-0.[illegible] 03	0.	-0.[illegible] 03	0.	0.[illegible] 03
5	0.	-0.7262227E 03 [illegible]	0.	-0.[illegible] 03	0.	0.[illegible] 03
6	0.	0.	0.	0.	0.	0.
7	0.[illegible] 03	0.	0.	0.	0.[illegible] 03	0.[illegible] 03
8	0.1622247E 02 [illegible]	0.2330[illegible] 02	0.3622230E 03 [illegible]	-0.[illegible] 03	0.[illegible] 03	0.[illegible] 03
9	-0.5284448E 02 [illegible]	-0.1635921E 03 [illegible]	0.3119711E 03 [illegible]	-0.[illegible] 03	0.[illegible] 03	0.[illegible] 03
13 [illegible]	-0.[illegible] 03	0.	0.	-0.[illegible] 03	0.	0.[illegible] 03
19 [illegible]	-0.3362?6E 03 [illegible]	0.	0.	-0.[illegible] 03	0.	0.[illegible] 03
25 [illegible]	-0.2994?2E 03 [illegible]	0.	0.	-0.[illegible] 03	0.	0.[illegible] 03
31 [illegible]	-0.[illegible] 03	0.	0.	-0.[illegible] 03	0.	0.[illegible] 03

(Sheet 3 of 3)

PART VI: CONCLUSIONS AND RECOMMENDATIONS

53. The computer program WESLAYER has the capability of obtaining solutions for rigid multicomponent pavements with discontinuities. The foundation soil can be either elastic solid or layered elastic solid. Because of the length of computer time required and the limitation of two slabs, it is recommended that the program be used for research and analysis purposes.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Chou, Yu T.
Structural analysis computer programs for rigid multicomponent pavement structures with discontinuities--WESLIQID AND WESLAYER : Report 3 : Manual for the WESLAYER Finite Element Program / by Yu T. Chou (Geotechnical Laboratory, U.S. Army Engineer Waterways Experiment Station.) -- Vicksburg, Miss. : The Station, [1981.]
64 p. : ill. ; 27 cm. -- (Technical report / U.S. Army Engineer Waterways Experiment Station ; GL-81-6, Report 3.)
Cover title.
"May 1981."
"Prepared for Office, Chief of Engineers, U.S. Army, under Project No. 4A762719AT40, Work Units 001 and 003."
"Available from National Technical Information Service, Springfield, Va. 22161."

Chou, Yu T.
Structural analysis computer programs for rigid : ... 1981.
(Card 2)

1. Computer programs. 2. Finite element method. 3. Pavements. 4. WESLAYER (Computer program.) 5. WESLIQID (Computer program.) I. United States. Army. Corps of Engineers. Office of the Chief of Engineers. II. United States. Army Engineer Waterways Experiment Station. Geotechnical Laboratory. III. Title IV. Series: Technical report (United States. Army Engineer Waterways Experiment Station) ; GL-81-6, Report 3.
TA7.W34 no.GL-81-6 Report 3